City of Ketchikan Charcoal Point Wastewater Treatment Plant Application For A Modified NPDES Permit Under Section 301(h) Of The Clean Water Act

Tentative Decision Document

April 2025

United States Environmental Protection Agency

Region 10

1200 6th Avenue

Seattle, WA 98101

REGION 10 ADMINISTRATOR

SEATTLE, WA 98101

City of Ketchikan
Charcoal Point Wastewater Treatment Plant
Application for a Modified NPDES Permit Under
Section 301(h) of the Clean Water Act

Tentative Decision of the Regional Administrator
Pursuant to 40 CFR Part 125, Subpart G

I have reviewed the attached evaluation analyzing the merits of the City of Ketchikan's request and application for a variance from secondary treatment requirements of the Clean Water Act pursuant to Section 301(h) of the Act for the Charcoal Point wastewater treatment plant. It is my tentative decision that the City of Ketchikan be granted a variance pursuant to Section 301(h) of the Act for the Charcoal Point wastewater treatment plant in accordance with the terms, conditions, and limitations of the draft 301(h)-modified NPDES permit.

My decision is based on available information specific to the discharge. It is not intended to assess the need for secondary treatment in general, nor does it reflect on the necessity for secondary treatment by other publicly owned treatment works discharging to the marine environment.

Public notice and comment regarding this tentative decision and the accompanying draft NPDES permit is available to interested persons pursuant to 40 CFR Part 124. This tentative decision is subject to change based on information acquired during the public comment period. Following the public comment period on this tentative decision and accompanying draft NPDES permit, EPA Region 10 will issue a final decision under the procedures in 40 CFR Part 124.

/signed/ April 4, 2025
Emma Pokon
Regional Administrator

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1) Introduction

The City of Ketchikan, Alaska, ("the City," "the applicant," "Ketchikan," or "the permittee") has requested a renewal of its variance (sometimes informally called a "waiver" or "modification") under Section 301(h) of the Clean Water Act (the Act or CWA), 33 USC § 1311(h) from the secondary treatment requirements contained in Section 301(b)(1)(B) of the Act, 33 USC § 1311(b)(1)(B).

The United States Environmental Protection Agency, Region 10 (EPA) approved Ketchikan's most recent National Pollutant Discharge Elimination System (NPDES) permit for the Charcoal Point Wastewater Treatment Plant ("WWTP" or "the facility") and issued a CWA Section 301(h)-modified permit on December 27, 2001. The permit became effective on January 29, 2001, and expired on January 29, 2006. A timely and complete NPDES application for permit reissuance was submitted by the permittee on July 12, 2005. Pursuant to 40 CFR 122.6, the permit has been administratively continued and remains fully effective and enforceable.

The 301(h) variance is being sought for the City of Ketchikan Charcoal Point WWTP, a publicly owned treatment works (POTW). The applicant is seeking a 301(h) variance to discharge wastewater receiving less-than-secondary treatment from a single outfall into the Tongass Narrows. The effluent quality attainable by secondary treatment is defined in the regulations (40 CFR Part 133) in terms of total suspended solids (TSS), biochemical oxygen demand (BOD), and pH. Pursuant to 40 CFR Part 133.102, secondary treatment requirements for TSS, BOD_5, and pH are as follows:

TSS: (1) The 30-day average concentration shall not exceed 30 mg/l;

(2) The 7-day average concentration shall not exceed 45 mg/l; and

(3) The 30-day average percent removal shall not be less than 85%.

BOD_5: (1) The 30-day average concentration shall not exceed 30 mg/l;

(2) The 7-day average concentration shall not exceed 45 mg/l; and

(3) The 30-day average percent removal shall not be less than 85%.

pH: The pH of the effluent shall be maintained within the limits of 6.0 to 9.0 pH standard units.

The City requested a modification for TSS and BOD_5, but not pH.

This document presents the EPA Region 10's tentative findings, conclusions, and recommendations as to whether the applicant's proposed 301(h)-modified discharge (proposed discharge) will comply with the criteria set forth in sections 301(h) of the Act, as implemented by regulations at 40 CFR 125, Subpart G, and Alaska Water Quality Standards (Alaska WQS), as amended.

2) Decision Criteria

Under Section 301(b)(1)(B) of the Act, 33 USC § 1311(b)(1)(B), POTWs in existence on July 1, 1977, are required to meet effluent limits based on secondary treatment as defined by the Administrator of EPA ("the Administrator"). Secondary treatment is defined by the Administrator in terms of three parameters: TSS, BOD_5, and pH. Uniform national effluent limitations for these pollutants were promulgated and included in

National Pollutant Discharge Elimination System (NPDES) permits for POTWs issued under Section 402 of the CWA. POTWs were required to comply with these limitations by July 1, 1977.

Congress subsequently amended the Act, adding Section 301(h) which authorizes the Administrator, with state concurrence, to issue NPDES permits that modify the secondary treatment requirements of the Act with respect to certain discharges. P.L. 95-217, 91 Stat. 1566, as amended by P.L. 97-117, 95 Stat. 1623; and § 303 of the Water Quality Act of 1987. Section 301(h) provides that:

> *[T]he Administrator, with the concurrence of the State, may issue a permit under section 402 [of the Act] which modifies the requirements of subsection (b)(1)(B) of this section [the secondary treatment requirements] with respect to the discharge of any pollutant from a publicly owned treatment works into marine waters, if the applicant demonstrates to the satisfaction of the Administrator that:*

(1) there is an applicable water quality standard specific to the pollutant for which the modification is requested, which has been identified under section 304(a)(6) of [the CWA];
(2) the discharge of pollutants in accordance with such modified requirements will not interfere, alone or in combination with pollutants from other sources, with the attainment or maintenance of that water quality which assures protection of public water supplies and the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife, and allows recreational activities, in and on the water;
(3) the applicant has established a system for monitoring the impact of such discharge on a representative sample of aquatic biota, to the extent practicable, and the scope of the monitoring is limited to include only those scientific investigations which are necessary to study the effects of the proposed discharge;
(4) such modified requirements will not result in any additional requirements on any other point or nonpoint source;
(5) all applicable pretreatment requirements for sources introducing waste into such treatment works will be enforced;
(6) in the case of any treatment works serving a population of 50,000 or more, with respect to any toxic pollutant introduced into such works by an industrial discharger for which pollutant there is no applicable pretreatment requirement in effect, sources introducing waste into such works are in compliance with all applicable pretreatment requirements, the applicant has in effect a pretreatment program which, in combination with the treatment of discharges from such works, removes the same amount of such pollutant as would be removed if such works were to apply secondary treatment to discharges and if such works had no pretreatment program with respect to such pollutant;
(7) to the extent practicable, the applicant has established a schedule of activities designed to eliminate the entrance of toxic pollutants from nonindustrial sources into such treatment works;
(8) there will be no new or substantially increased discharges from the point source of the pollutant into which the modification applies above that volume of discharge specified in the permit; and
(9) the applicant at the time such modification becomes effective will be discharging effluent which has received at least primary or equivalent treatment and which meets the criteria established

> *under [section 304(a)(1) of the CWA] after initial mixing in the waters surrounding or adjacent to the point at which such effluent is discharged.*
>
> *For the purposes of this subsection the phrase "the discharge of any pollutant into marine waters" refers to a discharge into deep waters of the territorial sea or the waters of the contiguous zone, or into saline estuarine waters where there is strong tidal movement and other hydrological and geological characteristics which the Administrator determines necessary to allow compliance with paragraph (2) of this subsection, and [section 101(a)(2) of the Act]. For the purposes of paragraph (9), "primary or equivalent treatment" means treatment by screening, sedimentation, and skimming adequate to remove at least 30 percent of the biological oxygen demanding material and of the suspended solids in the treatment works influent, and disinfection, where appropriate. A municipality which applies secondary treatment shall be eligible to receive a permit pursuant to this subsection which modifies the requirements of subsection (b)(1)(B) of this section with respect to the discharge of any pollutant from any treatment works owned by such municipality into marine waters. No permit issued under this subsection shall authorize the discharge of sewage sludge into marine waters. In order for a permit to be issued under this subsection for the discharge of a pollutant into marine waters, such marine waters must exhibit characteristics assuring that water providing dilution does not contain significant amounts of previous discharged effluent from such treatment works. No permit issued under this subsection shall authorize the discharge of any pollutant into saline estuarine waters which at the time of application do not support a balanced, indigenous population of shellfish, fish and wildlife, or allow recreation in and on the waters or which exhibit ambient water quality below applicable water quality standards adopted for the protection of public water supplies, shellfish, fish and wildlife or recreational activities or such other standards necessary to assure support and protection of such uses. The prohibition contained in the preceding sentence shall apply without regard to the presence or absence of a causal relationship between such characteristics and the applicant's current or proposed discharge. Notwithstanding any of the other provisions of this subsection, no permit may be issued under this subsection for discharge of a pollutant into the New York Bight Apex consisting of the ocean waters of the Atlantic Ocean westward of 73 degrees 30 minutes west longitude and westward of 40 degrees 10 minutes north latitude.*

On August 9, 1994, the EPA promulgated final regulations implementing these statutory criteria at 40 CFR Part 125, Subpart G. The regulations provide that a Section 301(h)-modified NPDES permit may not be issued in violation of 40 CFR 125.59(b) which requires, among other things, compliance with provisions of the Coastal Zone Management Act, as amended, 16 USC § 1451 *et seq.*, the Endangered Species Act, as amended, 16 USC § 1531 *et seq.*, Title III of the Marine Protection Research and Sanctuaries Act, as amended, 16 USC § 1431 *et seq.*, the Magnuson-Stevens Fishery Conservation and Management Act, as amended, 16 USC § 1801 *et seq.*, and any other applicable provisions of local, state, and federal laws or Executive Orders.

In accordance with 40 CFR 125.59(i), the decision to grant or deny a CWA Section 301(h) waiver shall be made by the Administrator and shall be based on the applicant's demonstration that it has met all the requirements of 40 CFR 125.59 through 125.68, as described in this 301(h) Tentative Decision Document (301(h) TDD). The

EPA has reviewed all data submitted by the applicant in the context of applicable statutory and regulatory criteria and has presented its findings and conclusions in this 301(h) TDD.

3) SUMMARY OF FINDINGS

Based upon review of the data, references, and empirical evidence furnished by the applicant and other relevant sources, the EPA Region 10 makes the following tentative findings regarding the statutory and regulatory criteria:

1. The applicant's proposed discharge will comply with Alaska WQS for dissolved oxygen and turbidity. [CWA Section 301(h)(1); 40 CFR 125.61]
2. The applicant has demonstrated it can consistently achieve Alaska WQS and federal CWA Section 304(a)(1) water quality criteria beyond the zone of initial dilution (ZID). [CWA Section 301(h)(9); 40 CFR 125.62(a)]
3. The applicant's proposed discharge, alone or in combination with pollutants from other sources, will not adversely impact public water supplies or interfere with the protection and propagation of a balanced, indigenous population (BIP) of shellfish, fish, and wildlife, and will allow for recreational activities in an on the water. [CWA Section 301(h)(2); 40 CFR 125.62(b),(c),(d)]
4. The applicant has a well-established and adequate program to monitor the impact of its proposed discharge on aquatic biota and has demonstrated it has adequate resources to continue the program. These monitoring requirements will remain enforceable terms of the permit. [CWA Section 301(h)(3); 40 CFR 125.63]
5. The applicant's proposed discharge will not result in any additional treatment requirements on any other point or nonpoint sources. [CWA Section 301(h)(4); 40 CFR 125.64]
6. The facility serves a population of less than 50,000 people and has certified its discharge does not have any known industrial sources of toxic pollutants, so does not need to develop an urban area pretreatment program. [CWA Section 301(h)(5), 301(h)(6); 40 CFR 125.65, 40 CFR 125.66]
7. The applicant will continue to implement its nonindustrial source control program, consisting of public outreach and education designed to minimize the amount of toxic pollutants that enter the treatment system from nonindustrial sources. [CWA Section 301(h)(7); 40 CFR 125.66]
8. There will be no new or substantially increased discharges from the point source of the pollutants to which the 301(h) variance applies above those specified in the permit. [CWA Section 301(h)(8); 40 CFR 125.67]
9. The 301(h) modified permit contains the special conditions required regarding effluent limitations and mass loadings, schedules of compliance, and monitoring and reporting requirements. [40 CFR 125.68]
10. The discharge is not expected to conflict with applicable provisions of state, local, or other federal laws or Executive Orders, including compliance with the Endangered Species Act of 1973, as amended, 16 USC 1531 et seq.; Title III of the Marine Protection, Research and Sanctuaries Act, as amended, 16 USC 1431 et seq.; and the Magnuson-Stevens Fishery Conservation and Management Act, as amended, 16 USC § 1801 *et seq.*
11. The applicant has demonstrated the proposed discharge will comply with federal primary treatment requirements. [CWA Section 301(h)(9); 40 CFR 125.60]

4) TENTATIVE DECISION AND RECOMMENDATION

Based on the tentative findings in Section 3, above, the EPA has concluded that the applicant's proposed discharge will comply with the requirements of CWA Section 301(h) and 40 CFR 125, Subpart G, and recommends that the applicant be granted a CWA Section 301(h) variance in accordance with the above findings, contingent upon satisfaction of the following conditions:

1. All requirements determined necessary by the Alaska Department of Environmental Conservation (ADEC) as part of its final CWA Section 401 Certification to ensure that the proposed discharge will comply with applicable provisions of state law, including WQS, in accordance with Section 401 of the CWA and the regulations at 40 CFR 124.54 and 40 CFR 125.61(b)(2).
2. The determination by ADEC that the proposed discharge will not result in any additional treatment requirements on any other point or nonpoint sources, in accordance with 40 CFR 125.64.

5) DESCRIPTION OF TREATMENT SYSTEM

The treatment plant currently serves the City of Ketchikan, a population of approximately 8,000 people. The treatment plant also accepts approximately 5,000 gallons per month of septage from the Gateway Borough. The collection system is a separate sanitary sewer system. The design flows of the facility are presented below:

Average Wet Weather Design Flow: 4.0 million gallons per day (mgd).

Maximum Daily Design Flow: 7.2 mgd

Peak Hour Design Flow: 8.7 mgd

Actual Annual Average Monthly Flow (2019-2023): 1.79 – 1.97 mgd

Actual Average Monthly Flow Range (2019-2023) 1.48 – 2.76 mgd

Raw sewage enters the treatment works and is piped to three 25-inch diameter by 72-inch-long rotary screens with 0.04-inch openings, where larger solids and grit are removed. Sewage is then piped to four primary sedimentation tanks with an effective area of 5,000 ft^2 where settleable solids are removed. Treated sewage flows to the outfall pipe in Tongass Narrows which terminates ~274 meters offshore (~900 ft) at a depth of 32 meters (~105 ft) below mean lower low water (MLLW). At times, chlorine is added to the influent at the head of the treatment plant for operational purposes.

The sludge from the primary sedimentation tanks (and septage received from the Gateway Borough) is aerated and dewatered using a belt filter press after stabilization with hydrated lime (CaOH). The sludge is then composted at the Deer Mountain landfill where it is used as cover.

See Appendix A for facility and outfall locations and Appendix B for process flow diagrams.

6) DESCRIPTION OF RECEIVING WATERS

A. General Features

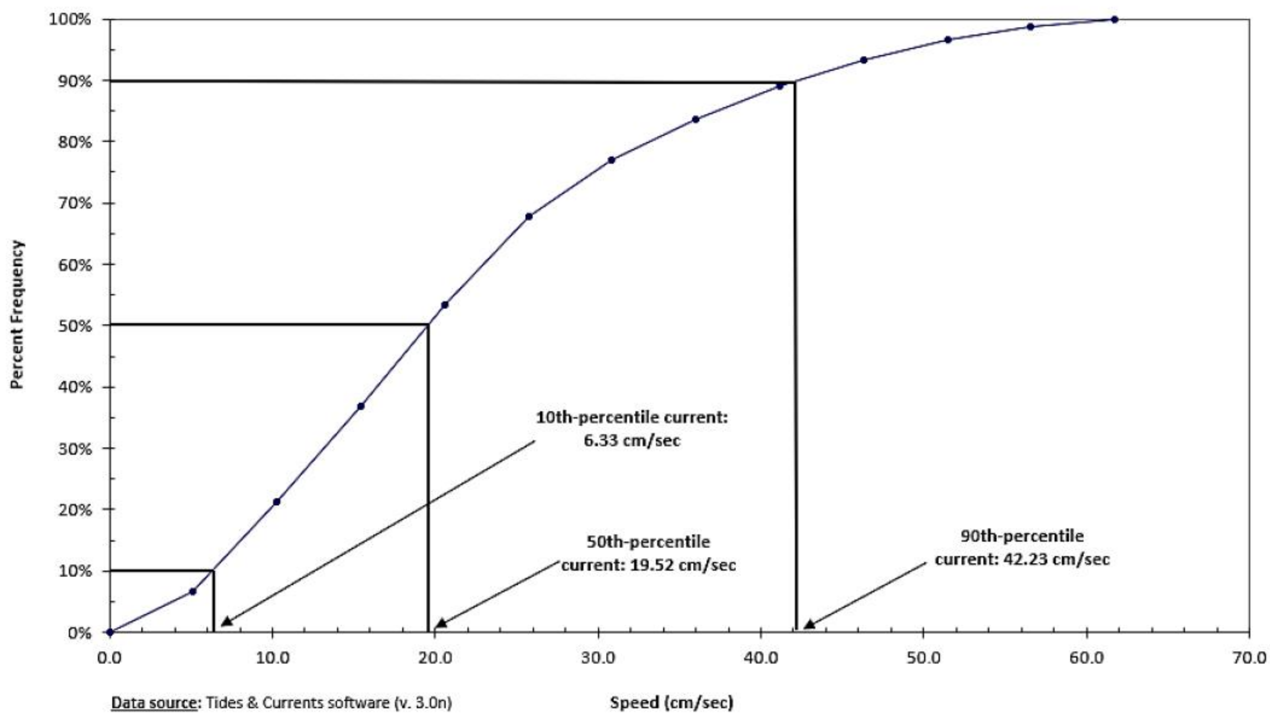
The WWTP discharges to the saline estuarine waters of Tongass Narrows at Charcoal Point. The Tongass Narrows is a glacial fjord channel in southeast Alaska's Inside Passage and includes the body of water between Revillagigedo Channel and Guard Island in Clarence Straight. The receiving water location is at the smallest width of the Narrows, ~400 meters wide (1,300 ft) and ~34 meters deep (110 ft). The ocean bottom consists of coarse gravels and shell fragments overlying fine sand, indicative of a high current channel. The Tongass Narrows has a net northwest seaward exchange (away from the City and Pennock Island) with the Gulf of Alaska.

Under 301(h) regulations at 40 CFR 125.58(v), the Tongass Narrows is classified as a saline estuary: *those semi-enclosed coastal water which have a free connection to the territorial sea, undergo net seaward exchange with ocean waters, and have salinities comparable to those of the ocean. Generally, these waters are near the mouth of estuaries and have cross-sectional annual mean salinities greater than twenty-five (25) parts per thousand.* The Tongass Narrows is a semi-enclosed coastal water with a free connection to the territorial seas, undergoes net seaward exchange with ocean waters, and has a salinity of ~30 parts per thousand.

The Tongass Narrows is protected for all marine use classes per 18 AAC 70.020(a)(2) and 18 AAC 70.050.

B. Currents and Flushing

Currents in the receiving water are generally reported to move northwestward and the water circulation patterns do not vary seasonally. The estimated 10th and 50th percentile current speeds in Tongass Narrows are 6.3 cm/sec and 19.5 cm/sec (0.14 and 0.44 miles per hour). Dilution modeling for the Tongass Narrows performed in 2021 (GLEC, 2021) used a conservative current speed of 5.9 cm/sec and no stratification. A cumulative frequency distribution plot of NOAA-predicted current velocities in Tongass Narrows is provided below.



Source: Technical Memorandum – Charcoal Point WWTP Outfall Modelling Evaluation, City of Ketchikan, Jacobs Engineering Group. 2023.

7) PHYSICAL CHARACTERISTICS OF THE DISCHARGE

A. Outfall/Diffuser Design and Initial Dilution

Pursuant to 40 CFR 125.62(a)(1), the outfall and diffuser must be located and designed to provide adequate initial dilution, dispersion, and transport of wastewater to meet all applicable water quality standards at and beyond the boundary of the ZID during periods of maximum stratification and during other periods when more critical situations may exist.

Once wastewater is treated it flows to the outfall piping. Outfall piping consists of a ~186 meter-long (609 ft) buried onshore pipe from the WWTP to the shoreline (103 meter-long (339 ft) 24-inch ductile iron pipe and 82 meter-long (270 ft) 24-inch (nominal) high-density polyethylene pipe) connected to a 218 meter-long (716 ft) long buried 24-inch (nominal) HDPE pipe from the shoreline connection to the toe of channel slope, and then connected 61 meter-long (200 ft) diffuser pipe section. The diffuser pipe section consists of six ports at 12 meter (40 ft) spacing: five 6” ports along the pipe spring-line with discharge ports on alternating sides and one 12” terminal diffuser port oriented in-line with the diffuser pipe. The high-density polyethylene and ductile iron pipe sections are anchored by concrete block anchors. The end of the outfall diffuser is located at approximately 55 21'21.51" N, 131 42'11.69" W (55.356094, -131.702828) at a depth of ~32 meters at MLLW (~105 ft).

Zone of Initial Dilution (ZID)

Section 301(h)(9) of the CWA and 40 CFR 125.62 require 301(h) discharges to meet state WQS and federal 304(a) criteria at the boundary of the ZID, which is the region of initial mixing surrounding or adjacent to the end of the outfall pipe or diffuser ports. The ZID may not be larger than allowed by mixing zone restrictions in applicable water quality standards. 40 CFR 125.58(dd). The dilution ratio achieved at the completion of initial mixing at the edge of the ZID is used to determine compliance with these requirements. Dilution is defined as the ratio of the total volume of the sample (ambient water plus effluent) to the volume of effluent in the sample. The ZID is not intended to describe the area bounding the entire mixing process or the total area impacted. Rather, the ZID, or region of *initial mixing* is the area of rapid, turbulent mixing of the effluent and receiving water and results from the interaction between the buoyancy and momentum of the discharge and the density and momentum of the receiving water. Initial dilution is normally complete within several minutes after discharge. In guidance, the EPA has operationally delimited the ZID to include the bottom area within a horizontal distance equal to the water depth from any point on the diffuser and the water column above that area. USEPA 1994. Beyond the ZID boundary (i.e., after initial mixing is complete) the effluent is diluted further by passive diffusion processes and far-field ambient receiving water conditions. The ZID is not inclusive of this far-field mixing process.

The 2001 permit used a dilution factor for the ZID of 100:1. The EPA was unable to recreate this dilution factor using available effluent and receiving water data. The EPA modeled the current discharge to determine the dilution achieved at the edge of the ZID using the discharge depth of the facility and tidal predictions from near the facility, in combination with recent effluent and receiving water data. In accordance with the 301(h) TSD, the EPA used data reflecting critical discharge and receiving water conditions to determine dilution under critical conditions. The dilution modeling report is included in Appendix G

According to the model, the discharge achieves initial mixing and a dilution of 52:1 approximately 13 meters (42 feet) from the discharge location at a depth of 22 meters (72 feet) within one minute of discharge under critical discharge and receiving water conditions. The EPA used 52:1 dilution as the basis for determining compliance with CWA section 301(h)(9) and 40 CFR 125.62. Consistent with the recommendations in the 301(h) TSD for setting spatial boundaries for the ZID, the EPA has established the spatial dimensions of the ZID to include the entire water column within a horizontal distance equal to the discharge depth at mean lower low water (32 meters) from any point along the diffuser.

Using these values, the ZID for the applicant's outfall was calculated to be a rectangle 64 meters (210 ft) long by 125 meters (410 ft) wide centered over the diffuser, with length and width being roughly parallel and perpendicular to shore, respectively.

The ZID dimension calculations are as follows:

Length (parallel to shore): 32 m + 32 m = 64 m (210 ft)

Width (perpendicular to shore): 32 m + 61 m + 32 m = 125 m (410 ft)

Please refer to Appendix A for a figure of the ZID.

8) APPLICATION OF STATUTORY AND REGULATORY CRITERIA

The sections below describe the statutory and regulatory requirements of 301(h) discharges and explains the basis for the permit conditions.

A. Compliance with Primary or Equivalent Treatment Requirements [CWA Section 301(h)(9); 40 CFR 125.60]

Under CWA Section 301(h)(9) and 40 CFR 125.60, the applicant must demonstrate it will be discharging effluent that has received at least primary or equivalent treatment at the time the 301(h)-modified permit becomes effective. 40 CFR 125.58(r) defines primary or equivalent treatment as treatment by screening, sedimentation, and skimming adequate to remove at least 30 percent of the biochemical oxygen demanding material and other suspended solids in the treatment works influent, and disinfection, where appropriate. To ensure the effluent has received primary or equivalent treatment, 40 CFR 125.60 requires the applicant to perform monitoring of their influent and effluent and assess BOD_5 and TSS removal rates based on a monthly average.

Applicants for 301(h) waivers request concentration (mg/L) and loading (lb/day) limits for BOD_5 and TSS based on what the facility can achieve. Therefore, the technology-based requirements for POTWs with 301(h) waivers are established on a case-by-case basis taking into consideration best professional judgement (BPJ), facility performance, the federal primary treatment standards, and state WQS.

1. Total Suspended Solids

The EPA reviewed influent and effluent monitoring data for TSS between 2019 and 2024. The facility has met minimum TSS percent removal requirements 100% of the time. The mimimum percent removal between 2019 and 2024 was 58%, with an average of 70% and a maximum of 80%. The TSS percent removal data from 2019 to 2024 are shown in Table 1.

Facility minimum percent removals for TSS meet federal primary treatment requirements under 40 CFR 125.60 and 40 CFR 125.58(r).

Table 1: INFLUENT AND EFFLUENT TSS DATA (2019-2024)

Statistic	Influent, TSS, mg/L Monthly Average	Effluent, TSS, mg/L Monthly Average	TSS Percent Removal
COUNT (n)	59	59	59
MEAN	156	42.5	70
MIN	97	28	58
MAX	243	59	80
STDV	34.6	7.9	4.7
CV	0.2	0.2	0.07
5th	115	31	62
95th	213	57	79

The applicant has demonstrated it will be discharging effluent that has received at least primary or equivalent treatment when the 301(h)-modified permit becomes effective [301(h)(9) and 40 CFR 125.60].

2. Biochemical Oxygen Demand

The EPA reviewed influent and effluent data for BOD_5 between 2019 and 2024. The facility has met minimum BOD_5 percent removal requirements 98% of the time. The mimimum percent removal between 2019 and 2024 was 27%, with an average of 42% and a maximum of 54%. The 27% removal occurred during April 2019 and can likely be attributed to dilute influent due to the significantly-above-average rainfall recorded that month. The BOD_5 percent removal data from 2019 to 2024 are shown in Table 2.

Table 2: INFLUENT AND EFFLUENT BOD5 DATA (2019-2024)

Statistic	Influent, BOD_5, mg/L Monthly Average	Effluent, BOD_5, mg/L Monthly Average	BOD_5 Percent Removal
COUNT (n)	59	59	59
MEAN	158	88.08	42
MIN	108	53	27
MAX	245	119	54
STDV	31.1	13.3	5.49
CV	0.20	0.15	0.13
5^{th}	119	63	33
95^{th}	205	110	52

The applicant has demonstrated it will be discharging effluent that has received at least primary or equivalent treatment when the 301(h)-modified permit becomes effective [301(h)(9) and 40 CFR 125.60].

B. ATTAINMENT OF WATER QUALITY STANDARDS RELATED TO TSS AND BOD_5 [CWA 301(h)(1); 40 CFR 125.61]

Under 40 CFR 125.61, which implements Section 301(h)(1), there must be water quality standards applicable to the pollutants for which the modification is requested, and the applicant must demonstrate that the proposed discharge will comply with these standards. The applicant has requested modified secondary treatment requirements for BOD_5, which affects dissolved oxygen (DO), and TSS, which affects the color or turbidity in the receiving water. The state of Alaska has water quality standards for DO and turbidity. The following analyses are based on an assessment of receiving water monitoring data conducted by the facility and submitted with their 2006 application. Complete receiving water data is in Appendix C.

1. Turbidity and Light Transmittance/Attenuation

Alaska WQS applicable to the estuarine waters of the Tongass Narrows provide that turbidity shall not exceed 25 nephelometric turbidity units (NTU), may not interfere with disinfection, may not cause detrimental effect on established levels of water supply treatment, and may not reduce the depth of the compensation point for photosynthetic activity by more than 10%. In addition, turbidity may not reduce the maximum secchi disc depth by more than 10%. Alaska WQS for turbidity can be found in Appendix E.

Secchi disk depth monitoring was not included in the 2001 permit, so no measurements were performed. Measurement of receiving water Secchi disk depths have been included as a requirement in the renewed permit.

The applicant provided 84 readings for turbidity in the receiving water at surface, mid, and bottom depths (bottom depth is 100 - 130 feet). Turbidity results were not provided for 2003 sampling events, and the facility reported that the readings were not reliable. Average receiving water turbidity values adjacent to the ZID were 5.8, 5.1, and 5.2 NTU for surface, mid, and bottom depths respectively. Values at reference sites were 5.2, 5.1, and 5.1 NTU for surface, mid, and bottom depths respectively. Historically the ambient turbidity values at the ZID boundary are below 25 NTUs, and within 1.0 NTU of reference sites. Based upon these results, the discharge is not expected to result in an excursion above Alaska WQS for turbidity.

The change in suspended solids in the water column is indirectly related to turbidity measurements. To further assess the potential for the discharge to cause or contribute to an excursion above Alaska WQS for turbidity and light transmittance, the EPA determined the suspended solids concentration after initial mixing at the edge of the ZID using formula B-32 from the 301(h) TSD. The results show a final suspended solids concentration of 1.25 mg/L at the edge of the ZID. See Appendix F for equations.

Based on the above analyses, the proposed discharge is expected to comply with AK WQS for turbidity and light transmittance/attenuation. See Appendix F for the full equations.

2. Dissolved Oxygen (DO)

The effect of the effluent on ambient DO can occur in the nearshore and farfield as effluent mixes with the receiving water and the oxygen demand of the effluent BOD_5 load is exerted. Pursuant to 40 CFR 125.61(b)(1) and 125.62(a)(1), the applicant must demonstrate that the proposed discharge will comply with water quality criteria for DO and that the outfall and diffuser are located and designed to provide adequate initial dilution, dispersion, and transport of wastewater such that the discharge does not exceed criteria at and beyond the ZID. Alaska WQS applicable to marine waters provide that the concentration of DO shall not be less than 6.0 mg/L for a depth of one meter and shall not be less than 4 mg/L at any point. DO concentrations in estuaries and tidal tributaries may not be less than 5.0 mg/L except where natural conditions cause this value to be depressed. In the previous permit, ADEC determined that the receiving waters classified as both coastal and estuarine must meet the standards for both (i.e., DO may not be less than 5.0 mg/L at any time or depth). Alaska WQS for DO are shown in Appendix E.

In accordance with the EPA's Amended Section 301(h) Technical Support Document (301(h) TSD), the EPA assessed attainment of the water quality criteria for DO based on review of effluent and receiving water monitoring data.

The applicant provided 180 values for DO from surface water quality monitoring conducted in April and October 2001; March, April, May, June, July, August, and two October in 2003; March April, and October of

2004; and March and April 2005. A total of 90 measurements were adjacent to the ZID (Sites WQA3 and WQA4) and 90 from reference stations (sites WQA1 and WQA4). Monitoring results are presented in Figure 1.

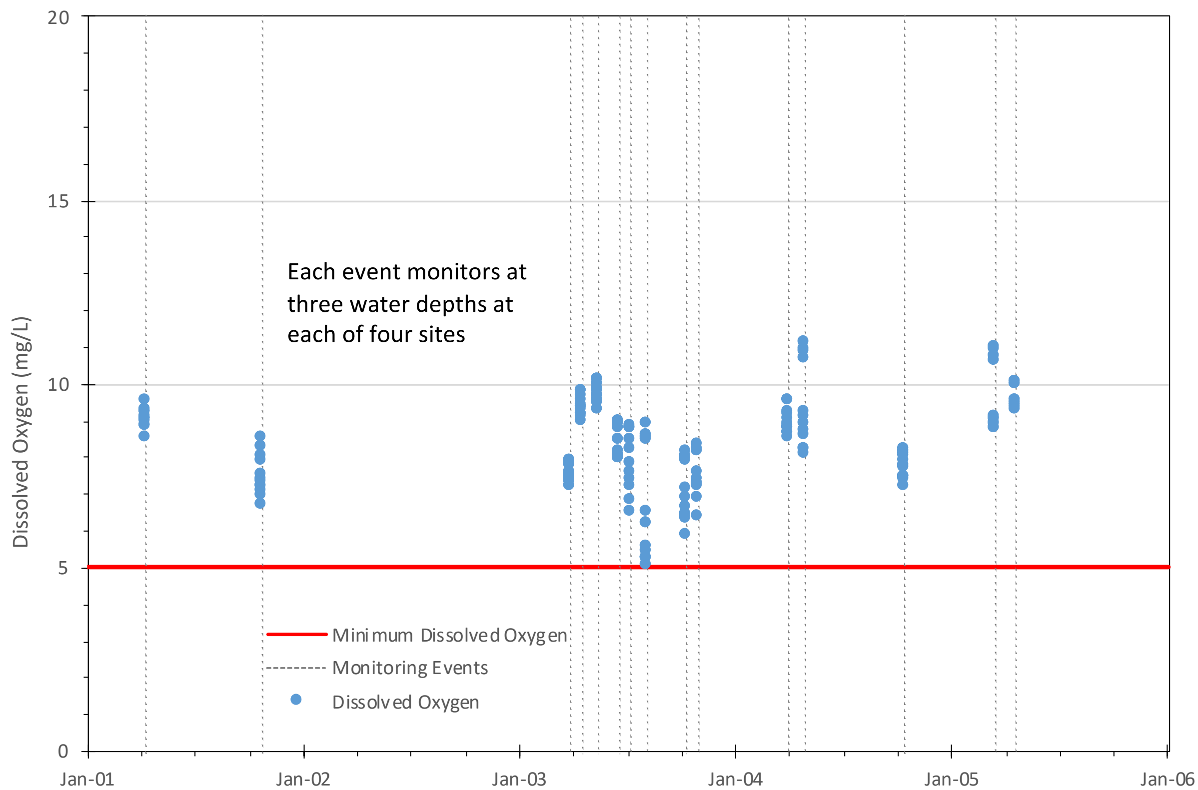


Figure 1 Ambient Dissolved Oxygen Monitoring Results for Tongass Narrows.

The 301(h) TSD (USEPA 1994) provides several procedures for assessing whether a proposed discharge will meet water quality criteria for DO at the edge of the ZID. These include calculating the final DO concentration of the effluent at the edge of the ZID using discharge and receiving water data and assessing the accumulation of suspended solids around the outfall.

DO Concentration at the Edge of the ZID

The EPA calculated the DO concentration at the ZID boundary using receiving water data provided by the applicant and the procedures described in Equation B-5 of the 301(h) TSD. The discharge results in a maximum near field DO depletion at the ZID of 0.2 mg/L (2.0%) from ambient concentrations. The minimum DO concentration of the receiving water immediately following initial dilution is between 5.0 mg/L and 6.5 mg/L and varies by water depth and location (reference or outfall). These values meet Alaska WQS as described in Appendix E. For additional information and the calculations used, refer to Appendix F.

Far Field DO Impacts

To assess the potential for far field impacts to DO, the final BOD_5 concentration after initial mixing was determined using the simplified procedures described in Appendix B of the 301(h) TSD and outlined in Appendix E of this 301(h) TDD. The calculation resulted in a final BOD5 concentration of 3.3 mg/L after initial mixing, a concentration that is not anticipated to cause or contribute to any measurable far field DO impacts beyond the ZID.

These equations were used to calculate the DO concentration (DO_f) in the wastefield at the completion of initial dilution at the edge of the ZID, using the following worst-case assumptions as recommended in the 301(h) TSD. This process was repeated for bottom, mid, and surface depths based on receiving water data, as shown in Appendix F. Because the expected DO depletion at all depths in minimal (0.2 mg/L), even when assuming zero DO in effluent, it is not expected that the discharge will result in a violation of AK WQS for dissolved oxygen at any depth.

Suspended Solids Accumulation

Impacts to DO concentrations resulting from the discharge of wastewater can also be assessed by examining the accumulation of suspended solids. 40 CFR 125.62 states that wastewater and particulates must be adequately dispersed following initial dilution so as not to adversely affect water use areas. The accumulation of suspended solids may lower DO in near-bottom waters and cause changes in the benthic communities. Accumulation of suspended solids in the vicinity of a discharge is influenced by the amount of solids discharged, the settling velocity distribution of the particles in the discharge, the plume height-of-rise, and current velocities. Hence, sedimentation of suspended solids is generally of little concern for small discharges into well-flushed receiving waters.

The questionnaire submitted by the applicant in 2006 states there are no known water quality issues associated with the accumulation of suspended solids from the discharge. In 2024, the applicant certified there are no known issues related to sediment accumulation in the vicinity of the discharge.

Figure B-2 in Appendix B of the 1994 Amended Section 301(h) Technical Support Document provides a simplified graphical method for small estuarine dischargers to assess the potential for suspended solids deposition around their outfall using the reported daily solids mass emission rate (y-axis in Fig. B-2) and the height-of-rise of the discharge (x-axis in Fig. B-2).

For the discharge height-of-rise, also known as the height to trapping or equilibrium level, dilution modeling should be used, or 0.6 times the water depth, whichever is larger. According to the dilution model (GLEC, 2021), the height-of-rise of the Ketchikan discharge is approximately 10 meters (~32 feet) and the discharge depth is ~ 32 meters (~105 feet); accordingly, 19 meters (~63 feet) was selected for the x-axis in Figure B-2 (0.6 x 32 m = 19).

The guidance recommends calculating the suspended solids daily mass emission rate using the average flow rate and an average suspended solids concentration. The reported monthly average flow rate from the Ketchikan WWTP between 2016 and 2021 was approximately 1.88 million gallons per day and the monthly average TSS concentration was 42.5 mg/L. To determine the daily loading of solids the monthly average concentration of TSS was multiplied by the reported average monthly flow and the loading conversion factor of 8.34. See Footnote 1 in Table 1 of the final permit for more information on mass loading calculations.

42.5 mg/L X 1.88 million gallons per day X 8.34 = 666 lbs/day.

Using this loading rate along the y-axis and 18 meters along the x-axis in Figure B-2, the projected steady state sediment accumulation is expected to be well below 25g/m2. The EPA considers this to be a negligible accumulation of sediment.

Based on the above analyses of DO depletion and suspended solids accumulation, the proposed discharge is expected to comply with AK WQS for dissolved oxygen. For the complete equations used in this analysis refer to E.

C. Attainment of Other Water Quality Standards and Impact Of the Discharge On Shellfish, Fish And Wildlife; Public Water Supplies; And Recreation [CWA Section 301(h)(2); 40 CFR 125.62]

CWA Section 301(h)(2) requires that the proposed discharge not interfere, either alone or in combination with other sources, with the attainment or maintenance of that water quality which assures protection of public water supplies and protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife, and allows recreational activities in and on the water. Pursuant to 40 CFR 125.62(a), the applicant's outfall and diffuser must be located and designed to provide adequate initial dilution, dispersion, and transport of wastewater such that the discharge does not exceed, at and beyond the ZID, all applicable EPA-approved state WQS and, where no such standards exist, the EPA's CWA Section 304(a)(1) aquatic life criteria for acute and chronic toxicity and human health criteria for carcinogens and noncarcinogens, after initial mixing in the waters surrounding or adjacent to the outfall. In addition, 40 CFR 125.59(b)(1) prohibits issuance of a 301(h)-modified permit that would not assure compliance with all applicable NPDES requirements of 40 CFR Part 122; under these requirements a permit must ensure compliance with all water quality standards.

Attainment of water quality criteria for DO and turbidity was previously discussed. However, in accordance with 40 CFR 125.62(a), the applicant must also demonstrate that the proposed discharge will attain other WQSs, including those for pH, temperature, toxic pollutants, and bacteria. The EPA used Alaska WQS and the processes described in the 301(h) TSD and the 1991 *Technical Support Document for Water Quality-based Toxics Control* to determine whether the proposed discharge has the reasonable potential to cause or contribute to an excursion above AK WQS, to calculate WQBELs, and to assess compliance with CWA Section 301(h)(2) and 40 CFR 125.62. To determine reasonable potential, the EPA compares the maximum projected receiving water concentration at the ZID boundary to the water quality criterion for that pollutant. If the projected receiving water concentration exceeds the criterion, there is reasonable potential for that pollutant to cause or contribute to an excursion above AK WQS, and a WQBEL must be included in the permit. If a permittee is unable to meet their WQBEL it would fail to satisfy CWA Section 301(h)(9) and 40 CFR 125.62 and would be ineligible for a CWA Section 301(h) modification.

Pursuant to 40 CFR 125.62(a)(1)(iv), the EPA's evaluation of compliance with WQSs must be based upon conditions reflecting periods of maximum stratification and during other periods when discharge characteristics, water quality, biological seasons, or oceanographic conditions indicate more critical situations may exist, commonly referred to as critical conditions.

1. pH

The applicant did not request a CWA Section 301(h) modification for pH, but the proposed discharge must still meet the WQS for pH. Alaska's WQSs provide that pH may not be less than 6.5 or greater than 8.5 and may not vary more than 0.2 pH unit outside of the naturally occurring range.

The effect of pH on the receiving water following initial dilution was estimated using Table 1. *Estimated pH Values After Initial Dilution* in the 301(h) TSD.

By utilizing an effluent pH value of 6.5 (actual minimum from DMR data was 6.8 s.u.), an effluent alkalinity of 0.5 meq/L (suggested as reasonable for primary effluents with no industrial component on TSD p. 65), a seawater temperature of 5°C (average temperature from surface water monitoring was 6.6°C) and a critical dilution of 52, the expected resulting pH range after initial dilution is 6.50 to 8.49 over an assumed seawater pH range of 6.50 to 8.50. This is within the range of 6.5 to 8.5.

The proposed discharge is expected to comply with Alaska WQS for pH after initial mixing at the edge of the ZID.

2. Temperature

Alaska's WQS for temperature provide that the discharge may not cause the temperature of the receiving water to exceed 15°C and the discharge may not cause the weekly average temperature to increase more than 1°C. The maximum rate of change may not exceed 0.5°C per hour. Normal daily temperature cycles may not be altered in amplitude or frequency.

The EPA reviewed surface water and DMR data from the facility to assess whether the modified discharge will comply with Alaska WQS for temperature. The maximum ocean temperature recorded near the trapping depth (mid-level depth) of the discharge during receiving water monitoring from 2001 to 2005 was 13.1°C, and the maximum recorded effluent temperature between 2019 and 2024 was 19.8°C. The EPA conducted a mass balance analysis using these values and calculated a final receiving water temperature of 13.2°C after initial dilution. Based upon the above analysis the proposed discharge is expected to comply with Alaska WQS for temperature at the edge of the ZID.

The maximum ocean temperature recorded at the trapping depth of the discharge during receiving water monitoring from 2001 to 2005 was 10.9 °C, and the maximum recorded effluent temperature between 2019 and 2024 was 19.8°C. The EPA conducted a mass balance analysis using these values and calculated a final receiving water temperature of 11.4°C after initial dilution.

Cd= Cu + (Ce – Cu)/Sa, where

Cd = Resultant temperature at edge of ZID, °C

Ce = Maximum projected effluent temperature, (19.8 °C)

Cu = Background receiving water temperature, °C (13.1 °C)

Sa = dilution factor (52:1)

Cd = 13.2°C

The temperature of the receiving water after initial dilution is 0.1°C greater than the ambient ocean temperature.

Based upon the above analysis, the proposed discharge is expected to comply with Alaska WQS for temperature at the boundary of the ZID.

3. Toxics

Alaska WQS for toxics for marine uses can be found in 18 AAC 70.020(b)(23) and the Alaska Water Quality Criteria Manual for Toxics (ADEC, 2022).

To assess whether the proposed discharge will comply with Alaska WQS for toxics after initial mixing at the edge of the ZID, the EPA reviewed DMR data collected between 2019 and 2024 and the results of two priority pollutant scans submitted with the permit application. Several pollutants were reported above their respective detection limits. Using this data, the EPA performed reasonable potential analyses using the numeric criteria in the Alaska Water Quality Criteria Manual for Toxics (ADEC 2022) and the processes outlined in the Technical Support Document for Water Quality-based Toxics Control (USEPA 1991). The only pollutant of concern with the reasonable potential to cause or contribute to an excursion above the Alaska WQS at the edge of the ZID is zinc.

The EPA has included water quality-based effluent limits for zinc and other toxics which were calculated using the dilutions provided by Alaska DEC in their draft 401 certification. The spatial areas and dilutions provided by the mixing zones authorized in the draft 401 certification are smaller than the spatial area and dilution provided by the ZID. Therefore, the effluent limitations for toxics within the draft permit will comply with Alaska WQS at the boundary of the ZID.

4. Bacteria

Alaska's WQS for bacteria are found at 18 AAC 17.020(b)(14).

Fecal Coliform

Alaska's most restrictive marine criterion for fecal coliform bacteria concentrations is in areas protected for the harvesting and use of raw mollusks and other aquatic life. The WQS specifies that the geometric mean of samples shall not exceed 14 MPN/100 mL, and that not more than 10 percent of the samples shall exceed:

- 43 MPN/100 mL for a five-tube decimal dilution test;
- 49 MPN/100 mL for a three-tube decimal dilution test;
- 28 MPN/100 mL for a twelve-tube single dilution test;
- 31 CFU/100 mL for a membrane filtration test.

This standard must be met at the edge of the ZID.

On December 21, 2000, ADEC provided a CWA Section 401 Certificate of Reasonable Assurance (401 Certification) that included a mixing zone for fecal coliform defined as a 3200-meter X 250-meter rectangle centered over the diffuser. The 2001 permit contains monthly average, average weekly, and maximum daily fecal coliform limits of 1,000,0000 FC/100mL, 1,250,000, and 1,500,000 FC/100mL, respectively. DMR data from the past 5 years shows monthly geometric mean fecal coliform values ranges from 10 to 860,000 FC/100mL, with a 95th percentile of 810,000 FC/100mL.

The 2001 permit required the facility to conduct fecal coliform sampling twice annually (once during the wet and once during the dry season), at five receiving water sampling sites located around the perimeter of the ADEC authorized mixing zone. Between 2019 and 2024 187 samples were taken. The highest FC value (47) was recorded in September 2023 at site F6, which is located at the souther boundary of the ZID directly adjacent to Ketchikan International Airport. Average and 95th percentile FC values at all six sites was 2.4 and 10, respectively.

Consistent with CWA section 301(h)(9) and 40 CFR 125.62, the EPA used the 52:1 dilution achieved at the edge of the ZID to assess compliance with CWA section 301(h)(9) and 40 CFR 125.62.

Using effluent data from 2019 to 2024 and the same process and equations as those used for toxics, the EPA conducted a reasonable potential analysis and determined fecal coliform has the reasonable potential to cause or contribute to an excursion above the Alaska WQS at the point of discharge. The EPA expects ADEC to require limits in the final 401 certification that are more stringent than the WQBELs EPA developed in the draft permit. For more information on the effluent limits for fecal coliform, refer to Section IV.A.3 of the Fact Sheet.

The effluent limits developed for fecal coliform will be protective of Alaska WQS after initial mixing at the edge of the ZID and will satisfy the requirements of CWA section 301(h)(9) and 40 CFR 125.63(a).

Enterococcus Bacteria

Enterococci bacteria are indicator organisms of harmful pathogens recommended by the EPA to protect primary contact recreation for marine waters. In October 2000, Congress amended the Clean Water Act with the Beaches Environmental Assessment and Coastal Health Act (BEACH Act, 33 U.S.C. 1313 et seq.). The amendment required the EPA to develop new or revised CWA criteria for pathogens and pathogen indicators. States and territories with coastal recreation waters were then required to adopt enterococci bacteria criteria into their WQS. The EPA approved Alaska's WQS for enterococcus in 2017. The WQS at 18 AAC 70.020(b)(14)(B)(i) for contact recreation specifies that the enterococci bacteria concentration shall not exceed 35 enterococci CFU/100mL, and not more than 10% of the samples may exceed a concentration of 130 enterococci CFU/100mL.

The 2001 permit does not contain an effluent limitation for enterococcus bacteria because there were no applicable enterococcus WQS in effect when the permit was issued in November 2001.

40 CFR 122.44(d)(1) requires the EPA to account for existing controls on discharges when determining whether a discharge has the reasonable potential to cause or contribute to an excursion of state WQS. The WWTP does not currently disinfect its effluent, resulting in the high bacterial loads observed in the available fecal coliform data. The 2001 permit did not require enterococcus monitoring, but it reasons that the high fecal coliform loads observed are also indicative of high loads of other pathogens commonly found in WWTP effluents, including enterococcus. With the available fecal coliform data and lack of disinfection capacity at the facility, EPA has determined there is reasonable potential for the discharge to cause or contribute to an excursion above Alaska WQS for enterococcus at the point of discharge.

The EPA derived WQBELs for fecal coliform by multiplying the dilution factor of 19.7:1 achieved at the edge of the anticipated chronic mixing zone by the criteria. It is expected that the Alaska DEC will include these final enterococcus limitations as a condition of 401 certification and provide the permittee five years to comply. The EPA has incorporated these limits into permit.

The effluent limit developed for enterococcus will be protective of Alaska WQS after initial mixing at the edge of the ZID and will satisfy the requirements of CWA section 301(h)(9) and 40 CFR 125.63(a).

D. Impact of the Discharge on Public Water Supplies [40 CFR 125.62(b)]

40 CFR 125.62(b) requires that the applicant's 301(h)-modified discharge must allow for the attainment or maintenance of water quality which assures protection of public water supplies and must not interfere with the use of planned or existing public water supplies. The receiving water is a saline estuary, and according to the 2006 permit application, there are no existing or planned public water supply intakes in the vicinity of the discharge. The discharge will have no effect on public water supplies and will not interfere with the use of planned or existing public water supplies.

E. Biological Impact of Discharge [40 CFR 125.62(c)]

40 CFR 125.62(c) requires that in addition to complying with applicable WQS, the proposed discharge must allow for the attainment or maintenance of water quality that assures the protection and propagation of a balanced indigenous population (BIP) of shellfish, fish, and wildlife. A BIP of shellfish, fish, and wildlife must exist immediately beyond the ZID and in all other areas beyond the ZID where marine life is actually or potentially affected by the applicant's discharge. In addition, conditions within or beyond the ZID must not cause or contribute to extreme adverse biological impacts, including, but not limited to, the destruction of distinctive habitats of limited distribution, the presence of disease epicenter, or the simulation of phytoplankton blooms which have adverse effects beyond the ZID, interfere with estuarine migratory pathways within the ZID, or result in the accumulation of toxic pollutants or pesticides at levels which exert adverse effects on the biota within the ZID.

In accordance with the guidance for small dischargers in the 301(h) TSD, the following characteristics of the discharge were considered indicators of a low potential for impact on biota in the vicinity of the discharge: the location of the discharge is greater than 10m, the steady-state accumulation of suspended solids is less than 25 g/m2, there is a low potential for impact on local fisheries, and there are no industrial users. Toxic conditions are not expected because the effluent achieves rapid mixing within minutes of discharge, minimizing the potential exposure area. There is no evidence that the ZID is a disease epicenter, interfering with estuarine migratory pathways, or resulting in the accumulation of toxics at levels exerting adverse effects on biota within the ZID.

The 2001 permit required the permittee to implement a biological monitoring program in order to monitor for discharge-related ecosystem impacts, evaluate whether the discharge changes the amount of organic material in seafloor sediment, determine whether the discharge changes the benthic community, and generate data that allows the EPA to evaluate BIP-related permit conditions. Under the program, the permittee was required to sample for total volatile solids (TVS) and conduct a benthic survey once during the permit term inside the ZID, at the southeast boundary of the ZID, and at two reference locations. The permittee performed the required sampling in June of 2005 and the results are presented in the Table below. TVS sampling showed higher average TVS concentrations at the two reference sites compared with the ZID and ZID boundary sites.

No sediment build-up was observed around the diffuser and no significant difference was observed in the benthic community structure or abundance between the two reference sites, ZID site, and ZID boundary site. and indicate there is no substantive difference in species composition. The results of the benthic survey and TVS analysis – which show greater species richness and less TVS at the ZID site compared with the reference sites – indicate the discharge is not resulting in extreme adverse biological impacts (see Appendix D). In addition, there have been no known cases of mass mortalities of fish or invertebrates, no increased incidence of disease in marine organisms, and no known cases of adverse biological impacts.

Considering the above evidence, the EPA has concluded the discharge allows for the attainment or maintenance of water quality that assures the protection and propagation of a BIP of shellfish, fish, and wildlife, and will not cause or contribute to adverse biological impacts. The permittee has satisfied the requirements of 40 CFR 125.62(c).

F. Impact of Discharge on Recreational Activities [40 CFR 125.62(d)]

Under 40 CFR 125.62(d), the applicant's discharge must allow for the attainment or maintenance of water quality that allows for recreational activities beyond the zone of initial dilution, including, without limitation, swimming, diving, boating, fishing, and picnicking, and sports activities along shorelines and beaches. There must be no federal, state, or local restrictions on recreational activities within the vicinity of the applicant's outfall unless such restrictions are routinely imposed around sewage outfalls.

The 2006 application stated that no impacts on recreational activities were expected due to the proposed discharge. Due to cold water temperatures, swimming is not expected to be common in Tongass Narrows. In their 1990 and 2006 Questionnaires, the facility indicated that recreational fishing for salmon, rockfish, and possibly halibut occur in the area beyond the ZID, however, no adverse effects have been reported. The limited size of the ZID and depth of the discharge limits the potential for adverse impacts to recreational activities in the area.

The 2001 permit required signs to be placed on the shoreline near the fecal coliform mixing zone and the outfall line that state primary treated domestic wastewater is being discharged, mixing zones exist, and certain activities such as the harvesting of shellfish for raw consumption and bathing should not take place within the mixing zone. The EPA has retained the requirement to place these signs on the shoreline and outfall line in the draft permit until the final fecal coliform and enterococcus limits are maintained.

The applicant has demonstrated that the proposed discharge meets the requirements to allow for the attainment or maintenance of water quality which allows for recreational activities beyond the ZID.

G. Establishment of Monitoring Programs [CWA 301(h)(3); 40 CFR 125.63]

Under 40 CFR 125.63, which implements Section 301(h)(3) of the CWA, the applicant must have a monitoring program designed to provide data to evaluate the impact of the proposed discharge on the marine biota, demonstrate compliance with applicable WQSs, and measure toxic substances in the discharge. The applicant must demonstrate the capability to implement these programs upon issuance of a 301(h)-modified NPDES permit. In accordance with 40 CFR 125.63(a)(2), the applicant's monitoring programs are subject to revision as may be required by the EPA.

1. Influent/Effluent Monitoring Program [40 CFR 125.63(d)]

40 CFR 125.63(d) requires an effluent monitoring program and Section 308 of the CWA and federal regulation 40 CFR 122.44(i) require monitoring in permits to determine compliance with effluent limitations. Monitoring may also be required to gather effluent and surface water data to determine if additional effluent limitations are required and/or to monitor effluent impacts on receiving water quality. Throughout the previous permit term (and the administratively continued period), the applicant faithfully submitted effluent monitoring data to the EPA as required by the 2001 permit. For a summary of effluent data from 2019 to 2024 refer to Appendix B of the Fact Sheet.

The draft permit retains largely the same effluent and influent monitoring requirements and includes several new requirements. Please refer to Part IV.B.1 of the Fact Sheet for a full discussion of new effluent monitoring requirements.

2. Receiving Water Quality Monitoring Program [40 CFR 125.63(c)]

40 CFR 125.63(c) requires that the receiving water quality monitoring program must provide data adequate to evaluate compliance with applicable WQS. The applicant proposes continuation of the current receiving water monitoring program. As in the case of effluent monitoring, NPDES permits include receiving water monitoring requirements to allow for compliance assessment, and to determine if additional effluent limitations and/or monitoring requirements are necessary in future permitting actions.

The EPA is retaining most of the receiving water monitoring program from the 2001 permit in the draft permit. Changes to the receiving water monitoring program include the addition of enterococcus to the suite of parameters analyzed and the movement of the ZID boundary sites from the edge of the 2001 mixing zone at 1600 meters to the edge of the ZID in the draft permit. Sampling at the edge of the 3,200-meter mixing zone is no longer required because it is not being reauthorized by ADEC; sampling is now required at the edge of the newly established 125-meter X 64-meter ZID discussed in Part 7.A.

3. Biological Monitoring Program [40 CFR 125.63(b)]

40 CFR 125.63(b) requires a permittee to implement a biological monitoring program that provides data adequate to evaluate the impact of the applicant's discharge on the marine biota. Such a program should, at a minimum, allow for evaluation of any ecosystem impacts; any changes in the amount of organic material in the seafloor sediment; any changes to benthic communities; and the effectiveness/bases for permit conditions.

Biological monitoring requirements in the 2001 permit included a sediment analysis for TVS and a benthic survey. Sampling was conducted near the middle of the diffuser within the ZID, at the southeastern boundary of the ZID, and at two reference locations 1000 meters northwest and southeast of the outfall. Based on the results of the TVS analysis of sediment and the sediment deposition analysis in Part 8.B.2., it does not appear that excess organic sediment is accumulating around the outfall compared to stations at the ZID boundary and reference sites.

Based on visual observations of the benthic infauna collected in sediment samples, it does not appear that the Ketchikan WWTP discharge is causing significant changes in the benthic community structure.

The Biological Monitoring Program from the 2001 permit is being largely retained in the final permit with the exception of the TVS component, which has been removed from the permit.

The 301(h) regulations at 40 CFR 125.63(b)(2) provide that small 301(h) applicants are not subject to sediment analysis requirements if they discharge at depths greater than 10 meters and can demonstrate through a suspended solids deposition analysis that there will be negligible seabed accumulation in the vicinity of the modified discharge.

The Ketchikan WWTP discharges at depths greater than 10 meters and the suspended solids deposition analysis provided in Part 8.B.2 demonstrates there will be negligible seabed accumulation in the vicinity of the discharge.

Therefore, the applicant has satisfied the requirement of 40 CFR 125.63(b)(2) and the requirement to conduct sediment TVS analysis has been removed from the permit.

H. Effect of Discharge on Other Point and Nonpoint Sources [CWA 301(h)(4); 40 CFR 125.64]

Under 40 CFR 125.64, which implements Section 301(h)(4) of the Act, the applicant's proposed discharge must not result in the imposition of additional treatment requirements on any other point or nonpoint source. The applicant reports that the proposed discharge would not place any additional treatment requirements on point or nonpoint sources. Pursuant to 40 CFR 125.64(b), the applicant is required to submit a determination signed by the state of Alaska indicating whether the applicant's discharge will result in an additional treatment pollution control, or other requirement on any other point or nonpoint sources. The state determination must include a discussion of the basis for its conclusion.

ADEC provided the determination required under 40 CFR Part 125.64 in their draft 401 certification. For additional information refer to Part M – State Determination and Concurrence.

I. Urban Area Pretreatment Program [CWA 301(h)(6); 40 CFR 125.65]

Under 40 CFR 125.65, dischargers serving a population greater than 50,000 are required to have a pretreatment program. The Ketchikan WWTP serves a population of ~8,000, so this provisions in not applicable.

J. Toxics Control Program [CWA 301(h)(7); 40 CFR 125.66]

1. Chemical Analysis and Toxic Pollutant Source Identification [40 CFR 125.66(a) and (b)]

Under 40 125.66(a) and (b), applicants are required to perform chemical testing for toxic pollutants and pesticides and identify the source of any parameters detected.

The 2001 permit required two toxic pollutant scans to be submitted with the permit reapplication. As previously discussed, the permittee conducted two toxic pollutant scans, and the EPA used the results in the development of the draft permit. Pursuant to 40 CFR 125.66, the renewed permit requires an updated toxics and pesticides scan and source identification analysis to be submitted at the time of permit reapplication

2. Industrial Pretreatment Program [40 CFR 125.66(c)]

40 CFR 125.66(c) requires that applicants that have known or suspected industrial sources of toxic pollutants shall have an approved pretreatment program in accordance with the requirements of 40 CFR Part 403 (Pretreatment Regulations). Pursuant to 40 CEFR 125.66(c)(2), this requirement does not apply to applicants that certify they have no known or suspected industrial sources of toxic pollutants or pesticides.

The City of Ketchikan has certified that there are no known or suspected industrial sources of toxic pollutants or pesticides in their discharge.

Pursuant to 40 CFR 126.66, the draft permit requires an updated industrial user survey be submitted at the time of permit reapplication or a certification of no industrial sources.

3. Nonindustrial Source Control Program [40 CFR 125.66(d)]

40 CFR 125.66(d), which implements Section 301(h)(6) of the Act, requires the applicant to submit a proposed public education program designed to minimize the entrance of non-industrial toxic pollutants and pesticides into its POTW. Applicants must also develop and implement additional nonindustrial source control programs on the earliest possible schedule.

A small section 301(h) applicant that certifies there are no known or suspected water quality, sediment accumulation, or biological problems related to toxic pollutants or pesticides in its discharge, is required only to develop the public education program. The applicant provided this certification on February 9, 2024, and has provided documentation regarding its ongoing public education efforts.

The Solid Waste Facility has a year-round hazmat drop to allow residents to discard small quantities of hazardous wastes such as: poisons, disinfectants, solvents, herbicides, used oil, acids, paint products, paint thinners, furniture stripper, antifreeze, wood preservatives, floor wax, and pesticides. This cost is covered under the residential area wide fees so there is not an extra fee to dispose of these hazardous waste. The City of Ketchikan WWTP partnered up with Ketchikan Public Utilities to mail out a public service post card called "No Wipes in the Pipes." The announcement covers: the problems associated with flushing wipes, facial tissue, diapers, cotton swabs, band aids, toys, sanitary items, socks, kitty litter and cigarettes. These postcards were mailed to all City of Ketchikan residents with an additional three dozen postcards printed and provided to a local apartment owner to distribute to current and future tenants. The Wastewater Division worked with Ketchikan Public Utilities to educate the public on our "No Wipes in the Pipes" slogan by putting a video out on social media (Facebook, and KPU TV) showing a plugged pump caused by "Wipes in the Pipes" being de-ragged. Along with the Video, the Wastewater Division also put a public announcement on the radio. Ketchikan provides free disposal of toxic and hazardous substances found in households. The Wastewater crew also gave three tours of the treatment facility and handed out pamphlets to Harbor Master condominium residents per the management request. Therefore, the City has satisfied the requirements for nonindustrial source control.

K. Effluent Volume and Amount of Pollutants Discharged [40 CFR 125.67]

Under 40 CFR 125.67, which implements Section 301(h)(7) of the Act, the applicant's proposed discharge may not result in any new or substantially increased discharges of the pollutant to which the modification applies above the discharge specified in the 301(h)-modified permit. The applicant has applied on the basis of the current discharge and does not propose any new or substantially increased discharges of TSS or BOD_5, the two parameters for which the facility has requested a waiver.

L. COMPLIANCE WITH OTHER APPLICABLE LAWS [40 CFR 125.59]

Under 40 CFR 125.59(b)(3), a 301(h)-modified permit may not be issued if such issuance would conflict with applicable provisions of state, local, or other federal laws or executive orders. As part of the application renewal, the applicant must demonstrate compliance with all applicable Alaska and federal laws and regulations, and executive orders, including the Coastal Zone Management Act, Marine Protection Research and Sanctuaries Act, the Endangered Species Act, and the Magnuson-Stevens Fishery Conservation and Management Act.

1. Coastal Zone Management Act

Alaska withdrew from the voluntary National Coastal Zone Management Program on July 1, 2011 (NOAA 2019c). Without State participation in the Coastal Zone Management Program Act, there is no consistency analysis to perform, and the EPA has fulfilled the requirements.

2. Marine Protection, Research, and Sanctuaries Act

Under 40 CFR 125.59(b)(3), no section 301(h) modified permit shall be issued if such issuance would conflict with Title III of the Marine Protection, Research, and Sanctuaries Act, 16 USC § 1431 *et seq.*, authorizes the Secretary of Commerce (i.e., NOAA) to designate and protect areas of the marine environment with special national significance due to their conservation, recreational, ecological, historical, scientific, cultural, archeological, educational or esthetic qualities as national marine sanctuaries. In the U.S., there are 14 national marine sanctuaries and 2 marine national monuments, none of which are in Alaska (NOAA 2019d).

The draft permit is therefore expected to comply with Title III of the Marine Protection, Research, and Sanctuaries Act.

3. Endangered or Threatened Species

Under 40 CFR 125.59(b)(3), no 301(h)-modified permit shall be issued if such issuance would conflict with the Endangered Species Act (ESA), 16 USC 1531 et seq. The ESA requires federal agencies to consult with the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS), or “the Services,” if any activity proposed to be permitted, funded, or undertaken could beneficially or adversely affect any threatened or endangered species (ESA -listed species) or designated critical habitat.

Pursuant to ESA Section 7, on August 30, 2024, the EPA requested concurrence from the NMFS that renewal of the 301(h)-modified NPDES permit to the Wrangell WWTP is not likely to adversely affect the following threatened, endangered, or candidate species or their designated critical habitats:

- Western Distinct Population Segment (Western DPS or WDPS) Steller sea lions, and
- Mexico DPS humpback whales
- Sunflower sea star

On October 15, 2024, the NMFS concurred with the EPA's determination that renewal of AK0021466 is not likely to adversely affect any ESA-listed species or designated critical habits under their jurisdiction. No ESA-listed species or designated critical habitat under the jurisdiction of USFWS were identified.

4. Essential Fish Habitat

Under 40 CFR 125.59(b)(3), no 301(h)-modified permit shall be issued if such issuance would conflict with the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), 16 USC 1801 et seq., which protects against adverse impacts to Essential Fish Habitat (EFH). The MSFCMA requires federal agencies to consult with NMFS when any activity proposed to be permitted, funded, or undertaken may have an adverse effect on designated EFH as defined by the Act. The EFH regulations define an adverse effect as any impact which reduces quality and/or quantity of EFH and may include direct (e.g., contamination or physical disruption), indirect (e.g., loss of prey, reduction in species' fecundity), site-specific, or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions.

The EPA prepared a EFH assessment to assess the impacts of the discharge on EFH and submitted it to NMFS on August 30, 2024. Based upon the analysis and conclusions of the EFH assessment, the reissuance of the 301(h)-modified NPDES permit to Ketchikan will not adversely affect EFH.

M. STATE DETERMINATION AND CONCURRENCE [40 CFR 125.61(b)(2); 40 CFR 125.64(d)]

Under 40 CFR 125.61(b)(2), the applicant must provide a determination signed by the state or interstate agency(s) authorized to provide certification under 40 CFR 124.53 and 124.54 that the proposed discharge will comply with applicable provisions of state law, including WQS. This determination must include a discussion of the basis for the conclusion reached. Furthermore, pursuant to 40 CFR 124.53 and 124.54, the state must either grant a certification pursuant to Section 401 of the CWA or waive this certification before the EPA may issue a 301(h)-modified permit. The applicant did not provide this certification at the time of application.

40 CFR 125.64(b) requires applicants to provide a determination from the state or interstate agency(s) having authority to establish wasteload allocations indicating whether the applicant's discharge will result in an additional treatment pollution control, or other requirement on any other point or nonpoint sources. The state determination shall include a discussion of the basis for its conclusion. The applicant did not submit this determination with their application.

The draft 401 certification includes the required determinations, and the EPA requested that ADEC provide final 401 certification and the determinations under 40 CFR 125.61(b)(2) and 125.64(b) during the public notice period of the draft permit and this 301(h) TDD.

9) References

ADEC (Alaska Department of Environmental Conservation). 2003. *18 AAC 70, Water Quality Standards, As Amended Through June 26, 2003.* Approved by EPA in 2004. Available at https://www.epa.gov/wqs-tech/water-quality-standards-regulations-alaska.

ADEC. 2020. Water Quality Measures in Alaska's Ports and Shipping Lanes: 2020 Annual Report. December 2020

Anderson, Kimberly L., Whitlock, John E., and Hardwood, Valerie J. 2005. *Persistence and Differential Survival of Fecal Indicator Bacteria in Subtropical Waters*. Applied and Environmental Microbiology. Vol. 71, No. 6.

Environmental Protection Agency (EPA). 2003. Dilution Models for Effluent Discharges, 4th Edition (Visual Plumes). United States Environmental Protection Agency, National Exposure Research Laboratory. Research Triangle Park, NC. March 2003. EPA/600/R-03/025.

Great Lakes Environmental Center, Inc. (GLEC). 2021. DRAFT Mixing Zone Dilution Modeling for Six Alaska POTWs. United States Environmental Protection Agency, Region X. EPA OW Contract: 68HERC20D0010; Task Order: 68HERV21F0114.

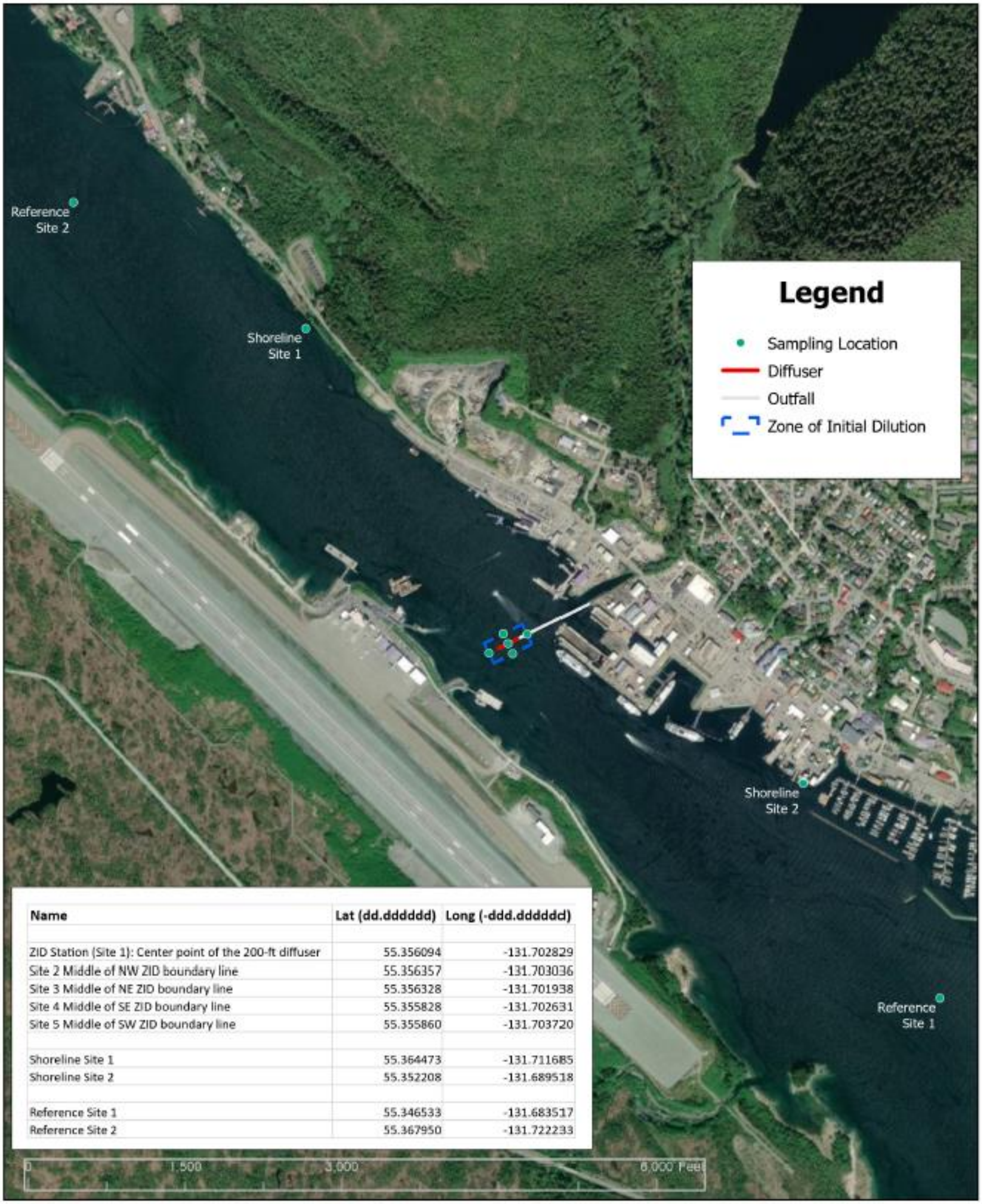
USEPA. 1994. Amended Section 301(h) Technical Support Document. EPA 842-B-94-007. September 1994.

10) Appendices

A. Facility and Outfall Locations

LOCATION MAP

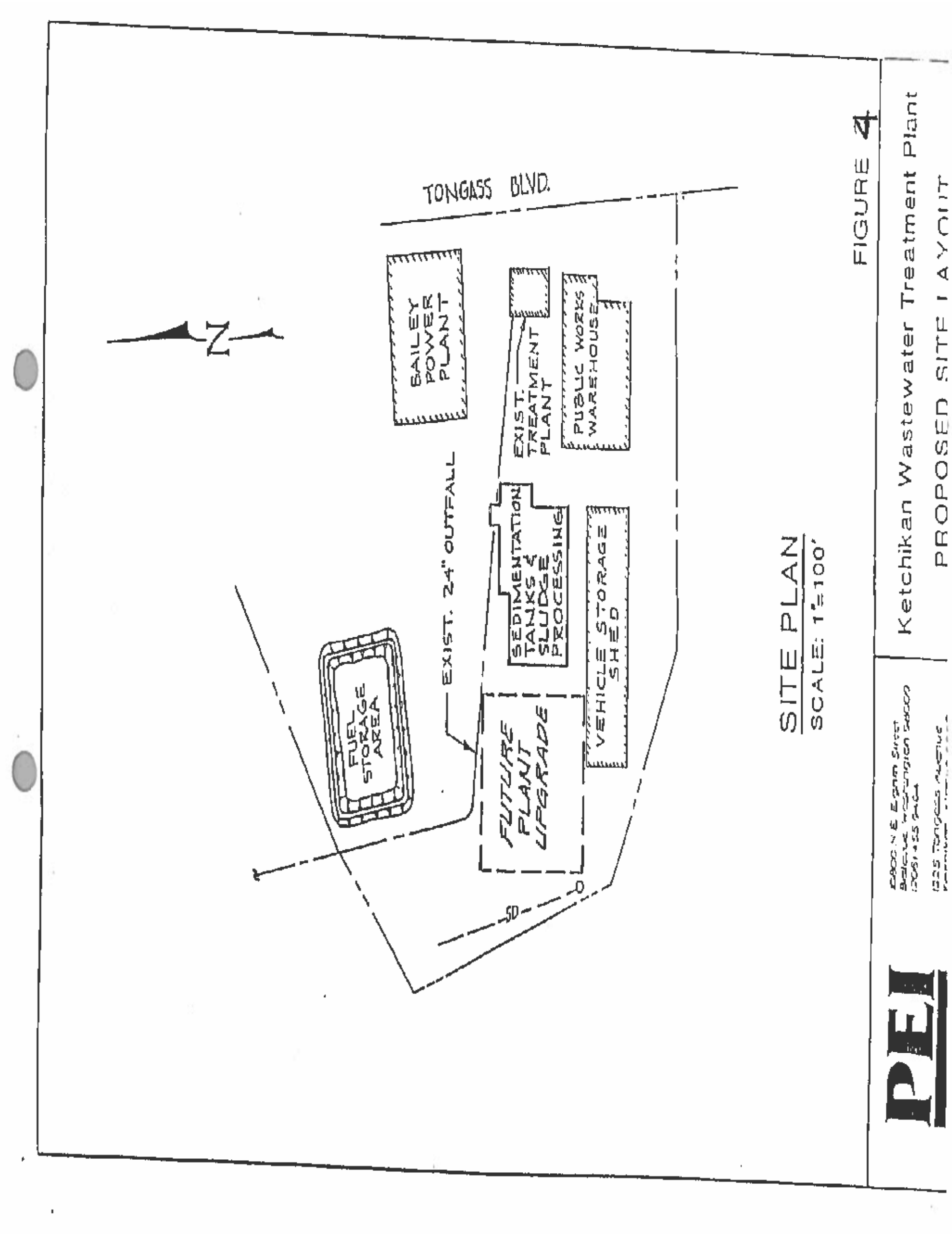
SOUTHEAST ALASKA



Name	Lat (dd.dddddd)	Long (-ddd.dddddd)
ZID Station (Site 1): Center point of the 200-ft diffuser	55.356094	-131.702829
Site 2 Middle of NW ZID boundary line	55.356357	-131.703036
Site 3 Middle of NE ZID boundary line	55.356328	-131.701938
Site 4 Middle of SE ZID boundary line	55.355828	-131.702631
Site 5 Middle of SW ZID boundary line	55.355860	-131.703720
Shoreline Site 1	55.364473	-131.711685
Shoreline Site 2	55.352208	-131.689518
Reference Site 1	55.346533	-131.683517
Reference Site 2	55.367950	-131.722233

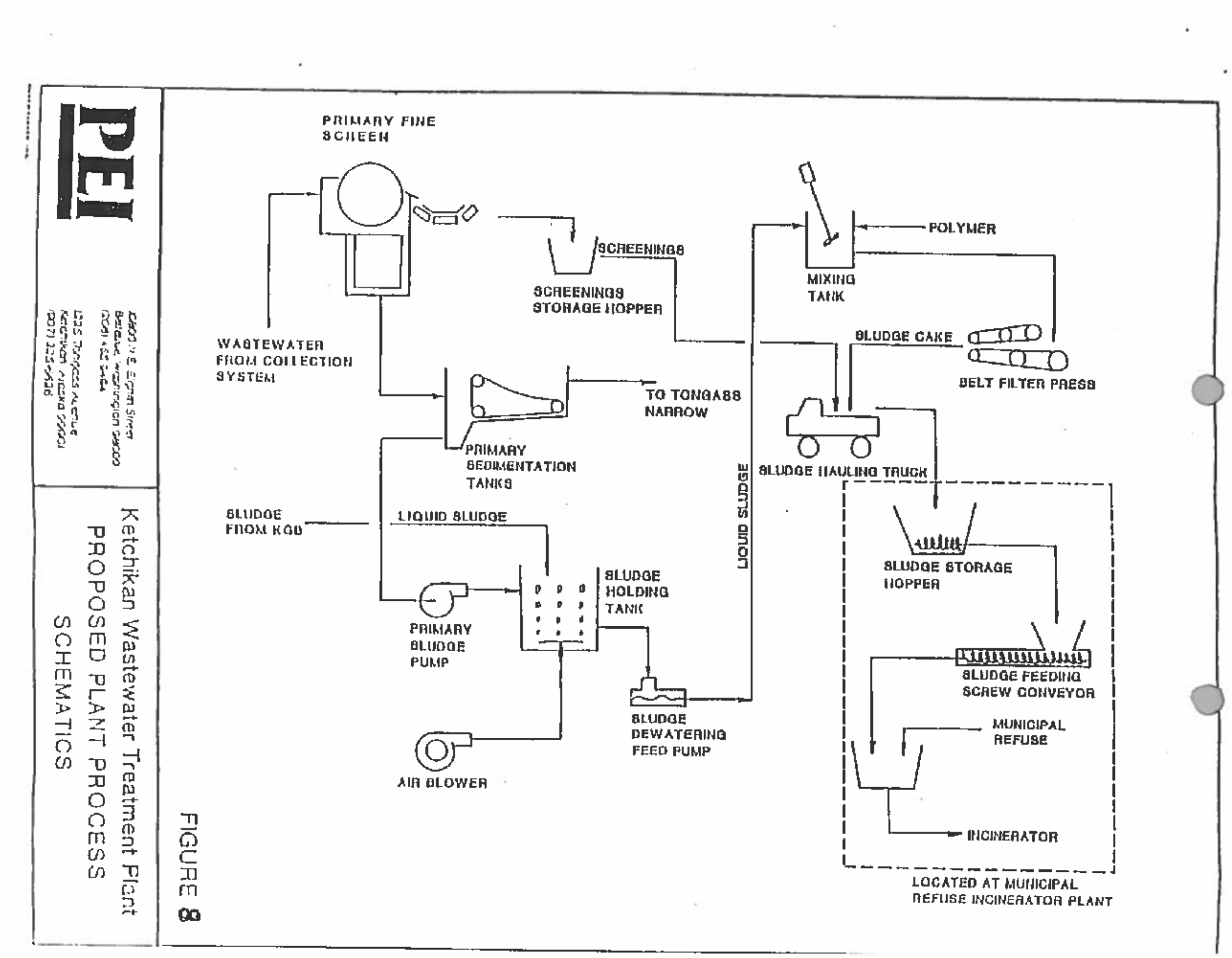
Receiving Water Sampling Locations Map
Ketchikan Wastewater Treatment Plant
NPDES Permit AK0021440 (Zoomed Out Extent)

EPA Region 10 GIS Team



TONGASS BLVD.
N
BAILEY POWER PLANT
EXIST. TREATMENT PLANT
PUBLIC WORKS WAREHOUSE
EXIST. 24" OUTFALL
SEDIMENTATION TANKS & SLUDGE PROCESSING
VEHICLE STORAGE SHED
FUEL STORAGE AREA
FUTURE PLANT UPGRADE
SD
SITE PLAN
SCALE: 1"=100'
FIGURE 4
Ketchikan Wastewater Treatment Plant
PROPOSED SITE LAYOUT
PEI

B. Facility Figures and Process Flow Diagram



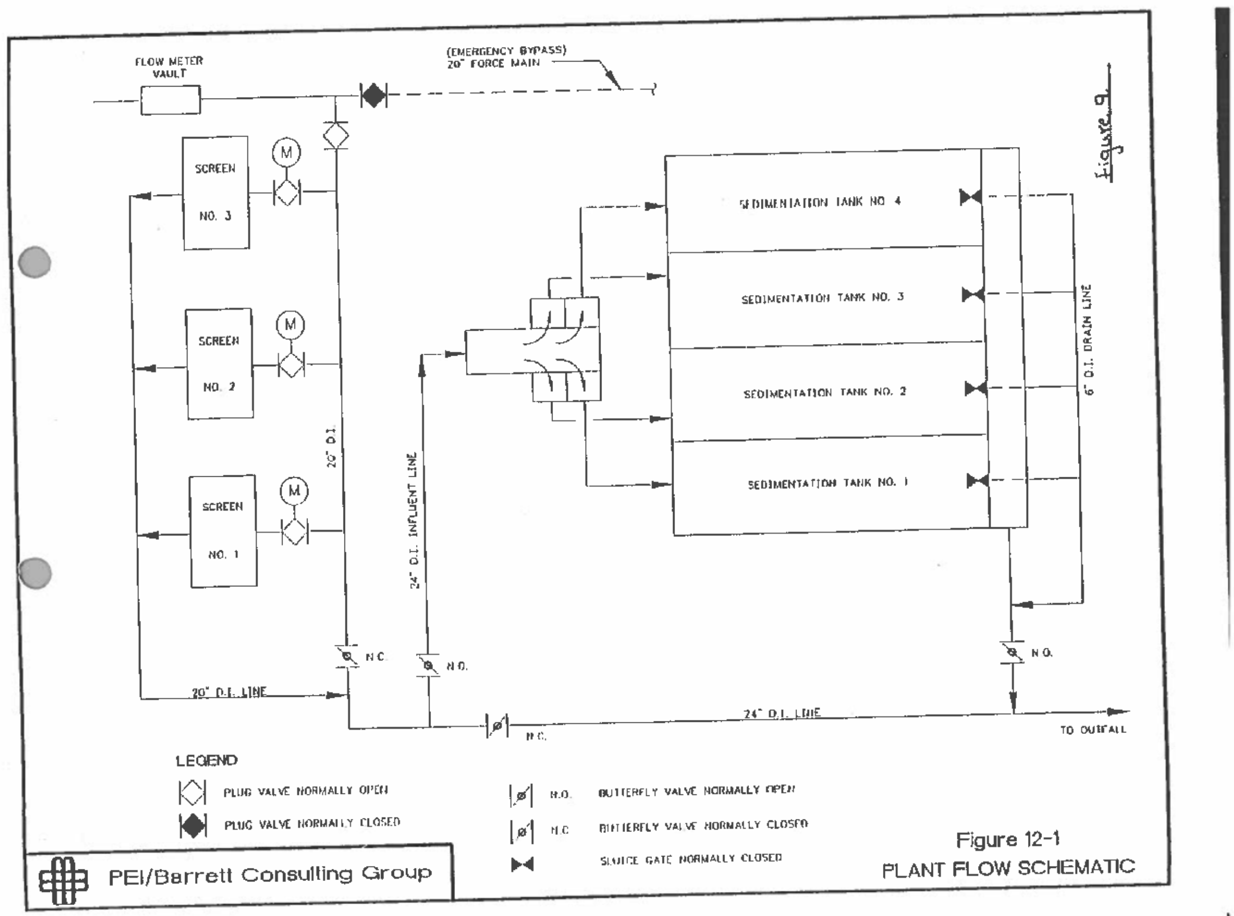


Figure 12-1
PLANT FLOW SCHEMATIC

C. Summary Statistics of Discharge Monitoring Data (2016-2021)

Parameter	BOD5, 20 deg. C (mg/L)	BOD5, 20 deg. C (mg/L)		BOD5 20 deg. C (lbs/day)		BOD5 (% removal)	TSS (mg/L)	TSS (mg/L)		TSS (lbs/day)		TSS (% removal)	Fecal coliform, MPN, 44.5 C (#/100mL)		Flow (mgd)		Nitrogen, ammonia total	D.O. (mg/L)		pH (S.U.)		Temp (C)
Statistical Basis	INFLUENT	DAILY MAX	MO AVG	DAILY MX	MO AVG	Min % Removal	INFLUENT	DAILY MX	MO AVG	DAILY MX	MO AVG	Min % Removal	DAILY MX	MO GEO	DAILY MAX	MO AVG	DAILY MX	MAXIMUM	MINIMUM	MAX	MIN	MO AVG
Effluent Limitation	N/A	200	120	1001	601	30	N/A	200	140	1001	701	30	1500000	1000000	3.6	0.6		17	2	8.5	6.5	N/A
1/1/2016	61	18	18	39.8	39.8	70	50	20	20	44.3	44.3	60	12000	12000	0.745	0.382	13	9.2	6.99	7.61	7.16	4.83
2/1/2016	110	13	13	31.7	31.7	88	112	15	15	36.6	36.6	86.6	16000	16000	0.695	0.359		7.94	5.15	7.6	7.16	6.45
3/1/2016	59	19	19	47	47	67.8	54	14	14	34.63	34.63	74.07	30000	30000	0.533	0.346		7.05	5.09	7.62	7.28	4.01
4/1/2016	51	18	18	72.4	72.4	64.7	38	15	15	60.34	60.34	60.5	44000	44000	0.822	0.343	4.4	9.8	5.02	7.57	7.19	10.71
5/1/2016	39	13	13	41	41	66.6	27	10	10	31.7	31.7	62.9	18000	18000	0.645	0.34		9.2	5.06	7.54	7.06	13.13
6/1/2016	120	18	18	41.6	41.4	85	120	5	5	11.5	11.5	95.8	90	90	0.311	0.247		6.5	3.35	7.68	7.4	17.2
7/1/2016	66	19	19	31.9	31.9	71	56	8	8	13.4	13.4	86	6000	6000	0.45471	0.292	24	5.84	2.67	7.67	7.24	18.4
8/1/2016	110	12	12	27.82	27.82	89.09	120	16	16	37.09	37.09	86.67	790	790	0.45523	0.26		5.97	4.39	7.78	7.4	17.63
9/1/2016	39	11	11	23.2	23.2	71.79	39	12	12	25.3	25.3	69.23	2100	2100	0.909	0.452		8.09	4.46	7.64	7.26	14.76
10/1/2016	36	12	12	21.7	21.7	66.6	34	7	7	12.68	12.68	79.4	1200	1200	0.584	0.282	9	7.37	4.6	7.65	7.13	9.8
11/1/2016	89	13	13	24.36	24.36	85.39	80	10	10	18.73	18.73	87.5	4100	4100	0.79265	0.379		8.32	3.95	7.62	7.28	7.62
12/1/2016	49	16	16	43.3	43.3	67.35	44	12	12	59	59	72.73	51000	51000	1.26693	0.435		10.62	7.27	7.61	6.99	3.39
1/1/2017	81	19	19	48.2	48.2	76.54	55	12	12	30.44	30.44	78.18	30000	30000	0.689	0.408	9.9	10.58	6.52	7.66	7.07	3.43
2/1/2017	50	12	12	33.75	33.75	76	40	9.5	9.5	26.72	26.72	76.25	25000	25000	0.896	0.379		8.47	6.35	7.55	7.02	3.07
3/1/2017	59	19	19	47	47	67.8	54	14	14	34.63	34.63	74.07	30000	30000	0.533	0.346		7.05	5.09	7.62	7.28	4.01
4/1/2017	54	17	17	45.45	45.45	68.52	50	14	14	37.43	37.43	72	6800	6800	0.625	0.317	11	6.03	3.55	7.6	7.17	9.25
5/1/2017	140	19	19	50.79	50.79	86.43	123	15	15	40.1	40.1	87.8	24000	24000	0.92952	0.368		7.03	4.45	7.59	7.02	12.24
6/1/2017	69	13	13	31.51	31.51	81.16	78	15	15	36.36	36.36	80.77	4500	4500	0.448	0.348		6.9	4.84	7.64	7.04	14.49
7/1/2017	120	14	14	42.04	42.04	88.33	89	11	11	33.03	33.03	87.64	860	860	0.50068	0.374	18	6.51	4.6	7.67	7.12	15.87
8/1/2017	74	20	20	62.14	62.14	72.97	69	13	13	40.39	40.39	81.16	25000	25000	1.23953	0.429		7.19	4.89	7.67	7.13	16.47
9/1/2017	120	17	17	35.01	35.01	85.8	98	15	15	30.89	30.89	84.69	20000	20000	1.352	0.439		7.8	4.69	7.7	7.06	14.2
10/1/2017	38	11	11	22.1	22.1	71.05	30	8.8	8.8	17.68	17.68	70.67	2000	2000	0.579	0.382	8.9	8.36	5.49	7.56	6.68	10.43
11/1/2017	53	12	12	29.89	29.89	77.36	60	16	16	39.85	39.85	73.33	4600	4600	0.515	0.316		8.76	5.3	7.56	7.12	5.16
12/1/2017	54	13	13	48.12	48.12	75.9	39	12	12	44.42	44.42	69.23	7300	7300	0.63	0.375		7.62	5.27	7.42	7.08	5.52
1/1/2018	69	15	15	41.18	41.18	78.26	51	15	15	41.18	41.18	70.59	7500	7500	0.701	0.358	10	8.3	5	7.46	7	5.34
2/1/2018	70	21	21	46.01	46.01	70	45	18	18	39.44	39.44	60	23000	23000	0.45522	0.317		9.04	6.46	7.58	7.05	2.26
3/1/2018	66	15	15	34.17	34.17	77.27	68	12	12	27.34	27.34	82.35	2800	2800	0.488	0.355		7.91	4.5	7.39	7.05	4.54
4/1/2018	77	14	14	27.5	27.5	81.8	69	16	16	31.5	31.5	76.8	2000	2000	0.56	0.286	15	9.33	4.2	7.49	7.01	8.15
5/1/2018	73	16	16	38.26	38.26	78.08	60	15	15	35.87	35.87	75	23000	23000	0.372	0.273		8.03	4.71	7.54	7.18	12.8
6/1/2018	90	8.4	8.4	17.35	17.35	90.67	115	48	48	99.17	99.17	58.26	12000	12000	0.335	0.235		7.3	4.2	7.63	7.4	16.04
7/1/2018	130	21	21	41.21	41.21	83.85	128	25	25	73.38	73.38	80.47	26000	26000	0.75165	0.283	28	7.71	5.63	7.75	6.5	17.76
8/1/2018	180	33	33	52.8	52.8	81.6	50	29	29	46.4	46.4	42	8800	8800	0.658	0.294		9.47	4.67	6.95	6.52	18.12
9/1/2018	95	23	23	56.08	56.08	75.79	92	12	12	29.26	29.26	86.96	20000	20000	0.87436	0.317		7.93	5.48	7.56	6.71	14.06
10/1/2018	130	16	16	26.37	26.37	87.69	116	8	8	13.18	13.18	93.1	72	72	0.855	0.351	14	8.8	5.63	7.6	7.26	10.71
11/1/2018	80	10	10	26.53	26.53	87.5	87	4	4	10.61	10.61	95.4	950	950	0.58014	0.41		8.05	5.8	7.52	7.34	8.64
12/1/2018	100	12	12	26.7	26.7	88	80	11	11	24.5	24.5	86.2	21000	21000	0.828	0.372		8.38	6.07	7.57	7.18	5.84
1/1/2019	52	13	13	30.03	30.03	75	47	17	17	39.27	39.27	63.83	15000	15000	0.83966	0.427	11	8.97	6.23	7.54	7.26	4.44
2/1/2019	52	17	17	40.16	40.16	67.31	48	17	17	40.16	40.16	64.58	36000	36000	0.36737	0.298		10.5	5.47	7.57	7.36	2.17
3/1/2019	240	14	14	27.92	27.92	94.17	280	12	12	23.93	23.93	95.71	3200	3200	0.42106	0.274		8.48	4.22	7.73	7.25	4.64
4/1/2019	180	18	18	27.2	27.2	90	142	17	17	25.7	25.7	88	21000	21000	0.421	0.288	17	8.48	4.22	7.64	7.3	8.86
5/1/2019	68	14	14	25.07	25.07	79	69	8	8	14.33	14.33	84.5	3600	3600	0.379	0.234		5.95	4.42	7.69	7.36	14.18
06/30/2019	150	16	16	24.6	24.6	89.3	150	4	4	6.16	6.16	96.7	160	160	0.575	0.264		6.85	4.5	7.67	7.18	16.05
07/31/2019	81	27	27	43.57	43.57	66.67	81	8	8	12.91	12.91	86.67	4500	4500	0.25781	0.212	4.8	9.42	7.19	7.57	7.33	18.63
08/31/2019	150	20	20	39.44	39.44	86.67	150	6.8	6.8	13.41	13.41	95.47	23000	23000	0.56346	0.31		9.42	4.71	7.45	7.19	17.09
09/30/2019	75	33	33	100.98	100.98	56	75	14	14	27.61	27.61	78.13	24000	24000	0.56346	0.362		7.75	4.83	7.23	6.51	14.78
10/31/2019	110	29	29	69.7	69.7	73.6	110	12	12	28.8	28.8	88.5	60000	60000	0.652	0.391	7.4	7.66	4.6	7.39	7.16	10.23
11/30/2019	140	100	100	296.7	296.7	28.5	140	16	16	47.4	47.4	69.2	21000	21000	0.786	0.559		7.39	5.41	7.36	7.1	9.06
12/31/2019	220	35	35	74.9	74.9	84.09	220	16	16	34.24	34.24	95.35	2300	2300	0.6799	0.412		9.2	5.42	7.5	7.12	5.59
01/31/2020	97	18	18	41.06	41.06	81.4	97	19	19	43.3	43.3	66.07	2700	2700	1.034	0.426	9.8	8.52	5.87	7.63	7.23	3.11
02/29/2020	49	12	12	47.5	47.5	75.5	49	16	16	63.4	63.4	72.4	30000	30000	0.762	0.459		9.87	7.43	7.68	7	4.67
03/31/2020	83	14	14	41.31	41.31	83.13	83	18	18	53.11	53.11	79.07	3100	3100	0.667	0.321		9.24	3.66	7.79	7.15	4.97
04/30/2020	41	14	14	26.72	26.72	65.85	41	16	16	30.54	30.54	65.22	14000	14000	0.48746	0.287	16	6.31	4.25	7.6	7.13	7.81
05/31/2020	130	23	23	47.13	47.13	82.31	130	16	16	32.78	32.78	86.21	4000	4000	0.4149	0.249		6.31	4.25	7.6	7.13	13.28
06/30/2020	110	28	28	79.34	79.34	74.55	110	22	22	62.34	62.34	80.36	45000	45000	0.43317	0.315		6.18	4.26	7.75	7.04	14.5
07/31/2020	180	28	28	51.34	51.34	84.44	180	9.2	9.2	16.87	16.87	93.48	58000	58000	0.78302	0.333	21	6.17	4.63	7.52	6.78	16.41
08/31/2020	74	13	13	46.33	46.33	82.43	74	4.7	4.7	16.75	16.75	93.56	680	680	0.711	0.453		7.8	5.49	7.54	7.27	15.57
09/30/2020	32	9.8	9.8	30.69	30.69	69.38	32	6	6	18.79	18.79	82.86	6600	6600	0.71189	0.3		7.8	5.28	7.61	7.35	14.2
10/31/2020	76	9.5	9.5	27.01	27.01	87.5	76	8	8	22.74	22.74	90	1800	1800	1.176	0.37	10	8.86	6.04	7.74	7.49	10.35
11/30/2020	64	15	15	44.4	44.4	76.56	64	15	15	44.4	44.4	75	35000	35000	1.88	0.497		9.02	6.4	7.6	7.44	6.91
12/31/2020	73	11	11	43.7	43.7	84.93	73	15	15	59.59	59.59	76.19	12000	12000	1.88	0.442		8.73	4.26	7.31	6.88	6.04
01/31/2021	37	16	16	57.42	57.42	56.76	37	16	16	57.42	57.42	48.39	27000	27000	0.7975	0.434	9.6	9.07	4.07	7.35	6.9	5.58
02/28/2021	62	16	16	29.21	29.21	74.19	62	20	20	36.51	36.51	61.54	5700	5700	0.762	0.36		8.5	5.15	7.31	6.85	3.46
03/31/2021	110	14	14	32.03	32.03	87.27	110	15	15	34.32	34.32	82.95	12000	12000	0.84164	0.436		8.6	5.96	7.23	6.72	5.29
04/30/2021	89	13	13	46	46	85.39	89	14	14	49.5	49.5	80.82	8400	8400	0.619	0.315	7.7	8.17	3.66	7.23	6.51	7.92
05/31/2021	120	14	14	38.75	38.75	88.3	120	11	11	30.44	30.44	89.4	4100	4100	0.341	0.27		6.67	4.45	7.61	6.99	12.5
06/30/2021	190	34	34	64.9	64.9	82.1	190	23	23	43.9	43.9	86.7	3300	3300	0.604	0.281		5.79	4.16	7.59	7.08	15.9
07/31/2021	76	22	22	36.73	36.73	71.05	76	8	8	13.36	13.36	88.89	5400	5400	0.36394	0.243	21	5.28	4.05	7.55	6.8	17.71
08/31/2021	180	20	20	35.2	35.2	88.9	180	10	10	17.6	17.6	94.3	7700	7700	0.494	0.314		5.21	4.1	7.54	6.87	16.85
Average	92.53	18.42	18.42	44.75	44.75	77.56	86.84	13.85	13.85	34.27	34.27	78.89	14892.68	14892.68	0.69	0.35	13.07	7.95	5.00	7.56	7.09	10.22
Maximum	240.00	100.00	100.00	296.70	296.70	94.17	280.00	48.00	48.00	99.17	99.17	96.70	60000.00	60000.00	1.88	0.56	28.00	10.62	7.43	7.79	7.49	18.63
Minimum	32.00	8.40	8.40	17.35	17.35	28.50	27.00	4.00	4.00	6.16	6.16	42.00	72.00	72.00	0.26	0.21	4.40	5.21	2.67	6.95	6.50	2.17
Count	68.00	68.00	68.00	68.00	68.00	68.00	68.00	68.00	68.00	68.00	68.00	68.00	68.00	68.00	68.00	68.00	23.00	68.00	68.00	68.00	68.00	68.00
Std Dev	46.71	11.75	11.75	34.53	34.53	10.56	48.56	6.43	6.43	16.78	16.78	12.02	14639.29	14639.29	0.31	0.07	6.10	1.29	0.97	0.15	0.23	5.15
CV	0.50	0.64	0.64	0.77	0.77	0.14	0.56	0.46	0.46	0.49	0.49	0.15	0.98	0.98	0.45	0.20	0.47	0.16	0.19	0.02	0.03	0.50
99th Percntile	226.60	56.45	56.45	165.57	165.57	91.83	239.80	35.27	35.27	81.89	81.89	96.10	58660.00	58660.00	1.88	0.52	27.12	10.59	7.32	7.78	7.46	18.48
95th Percentile	185.50	33.55	33.55	77.34	77.34	89.69	185.50	24.10	24.10	62.92	62.92	95.60	48300.00	48300.00	1.31	0.46	27.20	10.22	7.10	7.75	7.40	17.96
5th Percentile	37.45	9.89	9.89	22.60	22.60	60.33	32.90	4.84	4.84	12.03	12.03	59.04	394.00	394.00	0.34	0.24	4.48	5.81	3.60	7.23	6.51	3.09

D. Biological Survey and TVS Monitoring Results

Biological Survey and TVS Analysis				
	Reference Site – ~40 meters (130 ft) (Sample 1 – WQA 1)	Reference Site – ~40 meters (130 ft) (Sample 4 – WQA 2)	ZID Site – ~40 meters (130 ft) Sample 2	ZID Boundary ~40 meters (130 ft) (Sample 3- WQA 4)
Average TVS (% by weight)	6.27 6.29	5.43 5.33	1.56 1.61	3.21 3.85
Benthic Survey (visual observations)	Sea Urchins (Strongylocentrotus), Nerids, Hairy-Gilled Worms (Thelepus Crispus), Cement Worms, Tube Worms (Dodecaceria Fewkesi), Pile or Sand Worms (Nerios Vexillosa), Brown Algae (Desmarestiaceae), Limpets (Acmaeidoe).	Sea Urchins (Strongylocentrotus), Pile or Sand Worms (Nerios Vexillosa), Small Brittle Stars ((Amphipholis Squamata), Red Rock Crabs (Cancer Productus), Pink Scallop (Chlemys Rubida), Limpent (Acmaeidae), Chiton (Lepidochitonidae), Sea Squirts (Botryllidae), Scale Worms (Halosydna Brevisetosa), Periwinkles (Littorinidae), Anemone (Sagartriidae), Brown Algae (Desmarestiaceae), Tube worms (Dodecaceria Fewkesi), Cement Worms, Soft Coral.	Small Brittle Stars (Amphipholis Squamata), Rock Crabs (Cancer Productus), Limpets (Acmaeidoe), Cement Worms, TubeWorms (Dodecaceria Fewkesi), Brown Algae (Desmarestiaceae), Red Algae, Sea Squirts (Botryllidae), Basket/Feather Stars (Crinoidea), Round Worms.	Hennit Crabs (Pagurus) in moon snail shell, Spiny Pink Scallop (Chlemys Hastata), Hairy Sea Squirt (Boltemiavillosa), Tube Worms (Dodecaceria Fewkesi), Cement Worms, Feather Stars (Crinoidea), Red Cancer Crabs (Cancer Productus), Weathervane Scallop (Patinopecten), Coral Tube Worms, Sponge (Demospongia), Purple Sponge (Haliclona), Soft Coral, Brown Algae (Desmarestiaceae), Clear Worms, Butter Clam (Saxidomus Gigontea), Gumboot Chiton (Cryptochiton Stelleri), Limpets (Acmaeidoe), Brizoans, and Small Brittle Stars

				(Amphipholis Squamata)

E. Alaska WQS

Alaska WQS for Turbidity for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(24) TURBIDITY, FOR MARINE WATER USES	
(A) Water Supply (i) aquaculture	May not exceed 25 nephelometric turbidity units (NTU).
(A) Water Supply (ii) seafood processing	May not interfere with disinfection.
(A) Water Supply (iii) industrial	May not cause detrimental effects on established levels of water supply treatment.
(B) Water Recreation (i) contact recreation	Same as (24)(A)(i).
(B) Water Recreation (ii) secondary recreation	Same as (24)(A)(i).
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	May not reduce the depth of the compensation pointfor photosynthetic activity by more than 10%. May not reduce the maximum secchi disk depth by more than 10%.
(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	Same as (24)(C).

Alaska WQS for Dissolved Gas for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(15) DISSOLVED GAS, FOR MARINE WATER USES	

(B) Water Supply (i) aquaculture	Surface dissolved oxygen (D.O.) concentration in coastal water may not be less than 6.0 mg/l for a depth of one meter except when natural conditions cause this value to be depressed. D.O. may not be reduced below 4 mg/l at any point beneath the surface. D.O. concentrations in estuaries and tidal tributaries may not be less than 5.0 mg/l except where natural conditions cause this value to be depressed. In no case may D.O. levels exceed 17 mg/l. The concentration of total dissolved gas may not exceed 110% of saturation at any point of sample collection.
(A) Water Supply (ii) seafood processing	Not applicable.
(A) Water Supply (iii) industrial	Not applicable.
(C) Water Recreation (i) contact recreation	Same as (15)(A)(i).
(B) Water Recreation (ii) secondary recreation	Same as (15)(A)(i).
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	Same as (15)(A)(i).
(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	Same as (15)(A)(i).

Alaska WQS for pH for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(18) pH, for marine water uses (variation of pH for waters naturally outside the specified range must be toward the range)	
(A) Water Supply (i) Aquaculture	May not be less than 6.5 or greater than 8.5, and may not vary more than 0.2 pH unit outside of the naturally occurring range.
(A) Water Supply (ii) seafood processing	May not be less than 6.0 or greater than 8.5.
(A) Water Supply (iii) industrial	May not be less than 5.0 or greater than 9.0

(D) Water Recreation (i) contact recreation	May not be less than 6.0 or greater than 8.5. If the natural pH condition is outside this range, substances may not be added that cause any increase in buffering capacity of the water.
(B) Water Recreation (ii) secondary recreation	Same as (18)(A)(iii).
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	Same as (18)(A)(i).
(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	Same as (18)(A)(ii).

Alaska WQS for Temperature for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(22) TEMPERATURE, FOR MARINE WATER USES	
(C) Water Supply (i) aquaculture	May not cause the weekly average temperature toincrease more than 1° C. The maximum rate of change may not exceed 0.5° C per hour. Normal daily temperature cycles may not be altered inamplitude or frequency.
(A) Water Supply (ii) seafood processing	May not exceed 15° C.
(A) Water Supply (iii) industrial	May not exceed 25° C.
(E) Water Recreation (i) contact recreation	Not applicable.
(B) Water Recreation (ii) secondary recreation	Not applicable.
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	Same as (22)(A)(i).
(D) Harvesting for Consumptionof Raw Mollusks or Other Raw Aquatic Life	Same as (22)(A)(i).

Alaska WQS for Toxics for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(23) TOXIC AND OTHER DELETERIOUS ORGANIC AND INORGANIC SUBSTANCES, FOR MARINE WATER USES	
(D) Water Supply (i) aquaculture	Same as (23)(C).
(A) Water Supply (ii) seafood processing	The concentration of substances in water may not exceed the numeric criteria for aquatic life for marine water shown in the *Alaska Water Quality Criteria Manual* (see note 5). Substances may not be introduced that cause, or can reasonably be expected to cause, either singly or in combination, odor, taste, or other adverse effects on the use.
(A) Water Supply (iii) industrial	Concentrations of substances that pose hazards to worker contact may not be present.
(F) Water Recreation (i) contact recreation	There may be no concentrations of substances in water, that alone or in combination with other substances, make the water unfit or unsafe for the use.
(B) Water Recreation (ii) secondary recreation	Concentrations of substances that pose hazards to incidental human contact may not be present.
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	The concentration of substances in water may not exceed the numeric criteria for aquatic life for marine water and human health for consumption of aquatic organisms only shown in the *Alaska Water Quality Criteria Manual* (see note 5), or any chronic and acute criteria established in this chapter, for a toxic pollutant of concern, to protect sensitive and biologically important life stages of resident species of this state. There may be no concentrations of toxic substances in water or in shoreline or bottom sediments, that, singly or in combination, cause, or reasonably can be expected to cause, adverse effects on aquatic life or produce undesirable or nuisance aquatic life, except as authorized by this chapter. Substances may not be present in concentrations that individually or in combination impart undesirable odor or taste to fish or other aquatic organisms, as determined by either bioassay or organoleptic tests.
(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	Same as (23)(C).

Alaska WQS for Bacteria for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(14) BACTERIA, FOR MARINE WATER USES, (see note 1)	
(E) Water Supply (i) aquaculture	For products normally cooked, the geometric mean of samples taken in a 30-day period may not exceed 200fecal coliform/100 ml, and not more than 10% of the samples may exceed 400 fecal coliform/100 ml. For products not normally cooked, the geometric mean ofsamples taken in a 30-day period may not exceed 20 fecal coliform/100 ml, and not more than 10% of the samples may exceed 40 fecal coliform/100 ml.
(A) Water Supply (ii) seafood processing	In a 30-day period, the geometric mean of samples may not exceed 20 fecal coliform/100 ml, and not more than 10% of the samples may exceed 40 fecal coliform/100 ml.
(A) Water Supply (iii) industrial	Where worker contact is present, the geometric meanof samples taken in a 30-day period may not exceed 200 fecal coliform/100 ml, and not more than 10% of the samples may exceed 400 fecal coliform/100 ml.

(G) Water Recreation (i) contact recreation	In a 30-day period, the geometric mean of samples may not exceed 35 enterococci CFU/100 ml, and notmore than 10% of the samples may exceed a statistical threshold value (STV) of 130 enterococci CFU/100 ml.
(B) Water Recreation (ii) secondary recreation	In a 30-day period, the geometric mean of samples may not exceed 200 fecal coliform/100ml, and not more than 10% of the samples may exceed 400 fecal coliform/100ml.
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	Not applicable.
(D) Harvesting for Consumptionof Raw Mollusks or Other Raw Aquatic Life	The geometric mean of samples may not exceed 14 fecal coliform/100 ml; and not more than 10% ofthe samples may exceed; - 43 MPN per 100 ml for a five-tube decimal dilution test; - 49 MPN per 100 ml for a three-tube decimal dilution test; - 28 MPN per 100 ml for a twelve-tube single dilution test; - 31 CFU per 100 ml for a membrane filtrationtest (see note 14).

F. Equations and Analysis

Section 8.A.1: Attainment of TSS Standard

The EPA calculated the maximum change in the concentration of TSS at the edge of the ZID using formula B-32 from the 301(h) TSD. The average weekly TSS limitation of 65 mg/L and the modeled critical initial dilution of 52:1 were used in the equation. The results show a 1.25 mg/L increase in suspended solids in the receiving water after initial dilution, or 1.5%.

Formula B-32

SS = SSe/Sa

where,

SS = change in suspended solids concentration following initial dilution

SSe = effluent suspended solids concentration (65 mg/L)

Sa = critical initial dilution (52:1)

65/52 = 1.25 mg/L

Section 8.B.2: Attainment of DO Standard

The EPA calculated the final concentration of DO at the boundary of the ZID using equation B-5 from the 301(h) TSD. The analysis is presented in Table XX below.

Dissolved Oxygen Initial Depletion Analysis

Dissolved Oxygen in mg/L	Surface	Mid	Bottom	Notes
Ambient DO concentration (DO_a) =	6.7	5.4	5.1	minimum observed
Effluent DO concentration (DO_e) =	2.3	2.3	2.3	5th Percentile
Immediate DO demand (IDOD) =	3.0	3.0	3.0	Table B-3 301(h) TSD
Initial dilution (S_a) =	52.0	52.0	52.0	Dilution at edge of ZID
$DO_f = DO_a - (DO_a + IDOD - DO_e)/S_a$ =	6.5	5.3	5.0	Formula from Amended 301h TSD
Assuming 0 mg/L effluent (worst-case) $DO_f = DO_a - (DO_a + IDOD - DO_e)/S_a$ =	6.5	5.3	4.9	Worst-Case
Depletion (mg/L) =	-0.2	-0.1	-0.1	
Depletion (%) =	-2.1	-2.2	-2.2	

The final BOD_5 after initial dilution was also calculated to assess the potential for far field DO using a simplified procedure from Appendix B of the 301(h) TSD. The maximum reported average monthly BOD_5 value is first converted to ultimate BOD5 by multiplying it by the constant 1.46. The ultimate BOD_5 is then divided by the initial dilution factor (52) to determine the final BOD5 after initial dilution at the edge of the ZID.

Max BOD_5: 119 mg/L

Ultimate BOD_5: 119 mg/L x 1.46 = 174 mg/L

Final BOD_5: 174 mg/L ÷ 52 = 3.3 mg/L BOD5

A final BOD_5 concentration of 3.3 mg/L after initial dilution is not expected to cause or contribute to any measurable far field DO impacts.

The applicant did not provide calculations for far-field oxygen depression. However, as the expression of oxygen demand occurs over several days, the far-field dilution is appropriate. The dilution corresponding to 81 minutes of travel time from the Ketchikan diffuser, the furthest considered in GLEC, 2021, is equal to 179. Equation B-11 of amended 301(h) TSD can be used to evaluate if a far-field analysis is necessary, and is estimated by:

$DO_{STD} \leq DO_f - BOD_{fu}$

DO_{STD} is the DO standard

DO_f is the DO after initial mixing

BOD_{fu} is the ultimate BOD after initial mixing (119 mg/L)

The ADEC DO standard is 5.0 mg/L. Because we are interested in the far-field well mixed area the average of surface, mid, and bottom DO_f from the dissolved oxygen depletion analysis table above, equal to 5.6 mg/L. BOD_{fu} can be approximated by the effluent BOD_5 multiplied by the factor 1.46, and divided by the dilution, 119 mg/L *1.46 / 179 equaling 0.97 mg/L.

$DO_{STD} \leq DO_f - BOD_{fu}$

5.0 mg/L ≤ 6.3 mg/L – 0.97 mg/L

5.0 mg/L ≤ 5.36 mg/L

Because the inequality is true, no further analysis is required. Note also that the dilution considered in the analysis occurs after 81 minutes of float time. Additional dilution will occur as the tides move water through Tongass Narrows further reducing the DO deficit.

G. Dilution Modeling Report

FINAL

Mixing Zone Dilution Modeling for Six Alaska POTWs

Prepared for:

United States Environmental Protection Agency
Cincinnati Procurement Operations Division
Cincinnati, Ohio 45268

USEPA OW Contract: 68HERC20D0010; Task Order: 68HERV21F0114

Technical Support for National Pollutant Discharge
Elimination System (NPDES), Clean Water Act Section 301(h),
and Endangered Species Act Section 7 Implementation
in EPA Region 10 NPDES Permits Section

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MIXING ZONE DILUTION MODELING FOR SIX ALASKA POTWS

For each of the six POTWs of interest in southeast Alaska (Haines, Ketchikan, Petersburgh, Sitka, Skagway, and Wrangell) mixing zone dilution models were developed and applied to predict the steady-state dilution of effluent being discharged into the marine coastal receiving waters. Because of the nature of the discharges and receiving waters, initial dilution models within the EPA-approved Visual Plumes software (EPA 2003) were selected for use. From a modeling perspective, each of the receiving water mixing zones share several important characteristics that led to the selection of Visual Plumes, as opposed to the alternative EPA-approved modeling framework, CORMIX:

- Discharge of buoyant effluent into a deep (20-30 meter), stratified marine water body;
- No shoreline boundaries within 100 meters of the outfalls;
- Relatively small discharge flow rates (0.6-7 MGD); and
- No obstructions in the receiving waters to impede circulation near the outfalls, making tidal build-up of pollutants unlikely.

For each site, appropriate models were applied to predict average dilution at various distances (corresponding to 1-10 times the depth of discharge) from the discharge point, as well as the geometry (depth, width, etc.) of the plume itself. Aquatic life-based mixing zone analyses involve the concept of determining reasonable worst-case values for various parameters because the durations established for these water quality criteria vary for both acute and chronic toxicities (Washington DoE, 2018). The term *reasonable worst-case* refers to the value selected for a specific effluent or receiving water parameter. *Critical conditions* refer to a scenario involving reasonable worst-case parameters, which has been set up to run in a mixing zone model. For this work, steady-state mixing zone models were applied using a combination of parameters (e.g., effluent flow, current speed, density profile) to simulate critical conditions. The predictions were based on input data representing critical conditions demonstrated to minimize the dilution of effluent pollutants. It should be understood that each critical condition (by itself) has a low probability of occurrence.

It should also be understood that mixing zone modeling is not an exact science (Reese et al., 2021). With limited data and numerous variables, mixing zone sizes may be considered best estimates to ± 50%. Sensitivity analysis and comparison of alternative models were used to develop confidence in the dilution model predictions. All simulations explicitly included fecal coliform (FC) as a pollutant, which required the models to simulate bacterial decay in the receiving waters. Maximum effluent (end-of-pipe) FC concentrations were estimated for modeling by applying the EPA (1991) reasonable potential procedure to maximum monthly concentrations reported over the past five years in Discharge Monitoring Reports (DMRs) provided by EPA Region 10. The maximum effluent FC concentrations for each discharge are presented in Table 1 along with the dilution factors required to meet the Alaska marine water quality standards for harvesting for consumption of raw mollusks or other raw aquatic life (18 AAC 70 Water Quality Standards, amended as of March 5, 2020):

The geometric mean of samples may not exceed 14 fecal coliform/100 ml, and not more than 10% of the samples may exceed 43 MPN per 100 mL for a five-tube decimal dilution test.

Table 1. Maximum Effluent FC Concentrations Based on EPA (1991) Reasonable Potential Procedure (Maximum Monthly Concentrations Reported in DMRs Over the Past 5 Years)

City	Haines	Kechikan	Petersburg	Sitka	Skagway	Wrangell
Maximum expected effluent FC (daily max, 99%; n/100 mL)	2,100,000	2,900,000	2,000,000	3,700,000	2,600,00	190,000
Dilution factor[1] required to meet 14/100 mL FC criterion	150,000	210,000	140,000	270,000	190,000	14,000
Dilution factor required to meet 43/100 mL FC criterion	50,000	67,000	47,000	87,000	60,000	4,400

Model predictions of the size of the mixing zones required to attain these dilution factors are presented in the summary of this report.

Most mixing zone simulations required the combination of initial dilution and far-field models. Initial dilution models simulate the "initial mixing region" or "hydrodynamic mixing zone" defined to end where the self-induced turbulence of the discharge collapses under the influence of ambient stratification and initial dilution reaches its limiting value (EPA, 1994). At the end of this region/zone the waste field is established and then drifts with the ocean currents and is diffused by oceanic turbulence.

The initial dilution models included UM3, DKHW and NRFIELD, all contained within the Visual Plumes (VP) framework. Although the three initial dilution models run under the same VP interface, they differ in terms of origin and development, underlying assumptions, empirical datasets, solution techniques and coding. UM3 is a three-dimensional Updated Merge (UM) model for simulating single and multiport submerged diffusers. DKHW is an acronym for the Davis, Kannberg and Hirst model, a three-dimensional model for submerged single or multi-port diffusers. DKHW is limited to positively buoyant plumes and considers either single or multiport discharges at an arbitrary horizontal angle into a stratified, flowing current. NRFIELD is based on the Roberts, Snyder and Baumgartner (RSB) model, an empirical model for multiport diffusers (T-risers, each having two ports for a total of 4-ports) in stratified currents. A shortcoming of each of these initial dilution models in VP is their inability to recognize and address lateral boundary constraints, although that is not a major issue for these Alaskan mixing zone sites. Although the original 2001 version of VP is still available from EPA's CEAM site, it is currently unsupported and known to contain a number of errors (Frick et al. 2010; Frick and Roberts, 2019). We instead used the updated VP version 20, maintained and distributed by the California State Water Resources Control Board, Ocean Standards Unit (https://ftp.waterboards.ca.gov).

The Brooks far-field model was used to extend dilution simulations beyond the spatial bounds of initial dilution. Although this model is incorporated in VP, we also used a stand-alone spreadsheet version of the

[1] Dilution Factor, DF = (end of pipe) concentration/mixed concentration.

Brooks model, FARFIELD, that is contained in the Washington Department of Ecology (DoE), *Permit Calculation workbook* (https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Water-quality-permits-guidance). FARFIELD calculates dilution using the method of Brooks (1960) and is recommended by Frick et al. (2010) in lieu of using far-field predictions within VP, since the latter does not allow for the use of linear diffusivity as recommended in estuaries. FARFIELD was used to double-check the far-field results in VP, and in some instances to replace them.

The initial dilution models relied upon a variety of data to characterize the effluent, discharge outfall and receiving water. These data are summarized in Table 2. The data were gathered from a number of sources including EPA Region 10 and the State of Alaska; from the permittees as documented in permit files, as-built drawings and charts, etc.; tidal current predictions made by the National Oceanic and Atmospheric Administration (NOAA); and other literature sources found by Internet search.

All six of the POTWs discharge effluent using deeply-submerged outfalls with diffusers and multiple ports (Table 2). Haines and Petersburg both use two-diffuser ports, while the others use multiport diffusers with 6 to 16 ports. Modeling initial dilution from the four sites using multiport diffusers required additional considerations, because these diffusers have opposing ports (ports on both sides of the diffuser pipe that discharge effluent into opposite directions), creating co-flowing and counter-flowing plumes. Counter-flowing plumes are discharged opposing the ambient current and will generally rise and bend back into the direction from whence they came, eventually merging with the co-flowing plumes that are discharged on the opposite side of the pipe in the direction of the current. This is called cross-diffuser merging (EPA, 2003). Two alternative modeling approaches were applied to simulate initial mixing from opposing ports in the UM3 and DKHW models (NRFIELD models cross-diffuser merging directly). The first approach ("half spacing") treated the diffuser as if all ports are on one side with half the spacing. In the context of merging plumes, this approach works well when the distances of interest are somewhat beyond the point of merging.

The second approach ("downstream only") involves simulating only downstream ports. This necessitates doubling the flow per port (assuming there is an even number of ports in the diffuser) and increasing the diameter of the ports to maintain approximately the same densimetric Froude number. With this approach only the downstream ports would be used when determining spacing and number of ports. The Washington DoE Permit Writer's Manual, Appendix C (2018) discusses the merits of these approaches. When possible, we applied both approaches to modeling cross-diffuser merging and compared the results.

We assumed that all ports on a multiport diffuser discharged effluent flow equally and at the same depth. The multiport diffuser at Ketchikan was unique because it was the only diffuser that combined ports of different sizes. Five 6-inch opposing ports were spaced along a 12-inch manifold, and a sixth 12-inch port was located at the manifold's end. The CORMIX hydraulic module CorHyd (MixZone, 2020) was used to determine the flow distribution between the 6-inch ports and the 12-inch port. At a nominal flow rate of 5.35 MGD, CorHyd calculated that the 6-inch ports would discharge 52% of the flow, and the remaining 48% would be discharged from the 12-inch port. These same percentages were applied to other flow rates at Ketchikan. Initial model simulations suggested that the plumes emanating from the 12-inch port would not merge with the plume from the other ports, due to the 90° difference in port orientations. Therefore, these plumes were modeled separately.

The diffuser port orifice contraction coefficient is an initial dilution model hydraulic parameter that is specified according to how ports are machined in the diffuser pipe wall (EPA, 2003). For all of the outfalls except Sitka, sharp-edged ports were assumed, and contraction coefficients of 0.61 were specified. For Sitka, the port orifices were bell-shaped, so a contraction coefficient of 1.0 was applied.

Tidal current predictions were used to calculate 10th percentile and average current velocities at each site. The tidal prediction location nearest each discharge site was identified and tidal velocity predictions for 2021 were downloaded from the NOAA Tides & Currents web site (http://tidesandcurrents.noaa.gov). These data were imported into a spreadsheet and the predictions for the month in which the critical ambient conditions fell were selected. For Haines, Ketchikan and Skagway, 6-minute tidal velocity predictions were available. The tenth percentile of the absolute value of these velocities were calculated and used as the critical ambient velocity input for mixing zone dilution modeling. For the other locations, only times and velocities for ebb, slack and flood tides were available. The Excel FORECAST function was then used to interpolate hourly values from the tidal velocity predictions, and the tenth percentile of the absolute value of these interpolated hourly values was calculated and used for modeling[2]. These velocities, ranging from 1.4 to 5.9 cm/s, are presented in Table 2. The compass directions of tidal currents (also presented in Table 2) were based on the tidal current predictions, the orientation of the nearest shoreline (presuming currents to flow parallel to the shoreline), and other information from the permit files. The average hourly ebb and flood tidal velocities were calculated similarly and are also presented in Table 2 and were used in the model sensitivity analysis.

The decay of fecal coliform was included in the initial dilution and far-field models by using the Mancini (1978) bacteria model that incorporates four variables (salinity, temperature, solar insolation, and water column absorption) to determine the rate of first-order decay. Summertime solar insolation in southeast Alaska was based upon the models and measurements of Dissing and Wendler (1998). Summertime solar radiation flux, that takes into account both latitude and fractional cloud cover, averaged 190 Watts/m^2 (16.3 Langleys/hr) in the Alexander Archipelago. The bacterial decay model used ambient water temperature and salinity, and a default light absorption coefficient of 0.16, to calculate decay rates of ~0.0002/d. Decay of fecal coliform was found to be insignificant in comparison to physical dilution at the time and space scales of interest for mixing zone analysis.

[2] Comparison between linear interpolation and cubic spline interpolation of the tidal velocity predictions suggests that linear interpolation may yield average velocities that could be low by a factor of 1.6 to 2.3. The impact of this discrepancy on DF predictions will be demonstrated via sensitivity analysis.

Table 2. Summary of Data Used for Mixing Zone Dilution Modeling

City	Haines	Ketchikan	Petersburg	Sitka	Skagway	Wrangell
Permit	*AK0021385*	*AK0021440*	*AK0021458*	*AK0021474*	*AK0020010*	*AK0021466*
DMR data available	2011-2020	2013-18	2015-2019	2015-20	2007-19	2007-19
DMR data used	2016-2020	2013-2018	2015-2019	2015-2020	2014-2019	2015-2019
Permit Maximum Flow Rate (MGD[3])	2.9	7.2	3.6	5.3	0.63	3.0
monthly[4] average effluent temperature	12.0	14.6[5]	13.2	14.0	14.7	17.3
monthly maximum effluent temperature	15.8	20.5	14.6	15.0	17.3	18.4
Outfall						
distance from shore (m)	549	221	366	114	125	457
depth at LWWD (m)	21.3	29.9	18.3	24.4	18.3	30.5
number of diffuser ports	2 (3rd is capped)	6	2 (3 others capped)	16 bell-shaped	8	16
diffuser length (ft)	30	190	45.9	195	25	240
port diameter (in)	3	5@6", 1@12"	4	4	3	3
Elevation of ports above bottom (in)	8	12	9	18	6	6
Port spacing (ft)	15-30[6]	40 (20' apart on alternating sides of pipe)	10-34[6]	26 (13' apart on alternating sides of pipe)	7	32 (16' apart on alternating sides of pipe)
Port orientation	horizontal	horizontal (opposing/ alternating) + diffuser end	horizontal	horizontal opposing/ alternating	horizontal opposing	horizontal opposing/ alternating

[3] Million gallons per day.
[4] Average effluent temperature for month of limited dilution
[5] Average of maximum monthly effluent temperatures (no monthly averages in DMR)
[6] Port spacing is uncertain given information in permit fact sheet.

City	Haines	Ketchikan	Petersburg	Sitka	Skagway	Wrangell
VP discharge angle[7] (degrees)	90	115 (5x6" ports), 205 (1x12" port)	115	300	350	90
Receiving Water						
Water body	Portage Cove, Chinook Inlet	Tongass Narrows, Charcoal Point	Frederick Sound	Sitka Sound, Middle Channel	Tiaya Inlet	Zimovia Strait
tidal range (ft)	14.2	13	15	7.7	14.1	13
data source/file[8] name for ambient data	NA; used Skagway data	AK0021440_Ketchikan_temp_salinity	Petersburg_Receiving Water Data	Sitka Receiving Water Monitoring	Table 2-5_v2	Wrangell FC and RW Monitoring
Ambient salinity/temp profile limiting dilution	Skagway site 1, June 2005	Ketchikan site 3, July 1997	Petersburg site 1, August 2005	Sitka site C, July 2010	Skagway site 1, June 2005	Wrangell site 4, August 2016
NOAA tides & current predictions	Battery Point, Chinook Inlet (SEA0826)	East of Airport (SEA0711)	Cosmos Point (PCT3811)	Sitka Harbor, Channel off Harbor Island (PCT4166)	Tiaya Inlet (SEA0825)	Wrangell Harbor (PCT3131)
Tidal current 10th percentile (cm/s)	June: 2.1 @ 35', 2.8 @ 133'; 2.3 (interpolated to discharge depth)	July: 5.9 @87'	August: 1.6	July: 1.7	June: 1.4 @37'	August: 4.0
Tidal current average (Ebb/Flood, cm/s)	June: 10.2/10.7 @ 35', 11.3/16.1 @ 133'; 10.5/12.6 (interpolated to discharge depth)	July: 49.2/20.1 @87'	August: 10.4/7.8	July: 10.3/8.0	June: 6.9/12.2 @37'	August: 20.8/23.5
VP current angle[7] (degrees)	90	140	120	225	350	90

[7] Zero degrees is eastward.
[8] Names of electronic files provided by EPA Region 10 on March 31, 2021.

In the following sections, the modeling of effluent dilution in mixing zones at each site is presented and results are displayed in both tables and graphs. Text output from the VP and FARFIELD model simulations at each location are provided in an appendix to this report.

HAINES

The wastewater treated at Haines is discharged 549 m offshore in Portage Cove, Chinook Inlet (Figure 1), from a 2-port diffuser at a depth of 21.3 m (MLLW[9]). The permitted maximum flow rate is 2.9 MGD. Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2. The diffuser port spacing at Haines is uncertain (somewhere in the range of 15 to 30 ft.) due to one of three ports being closed. The models predicted lower DFs for the narrowest port spacing (15 ft.), so that spacing was used for all model simulations.

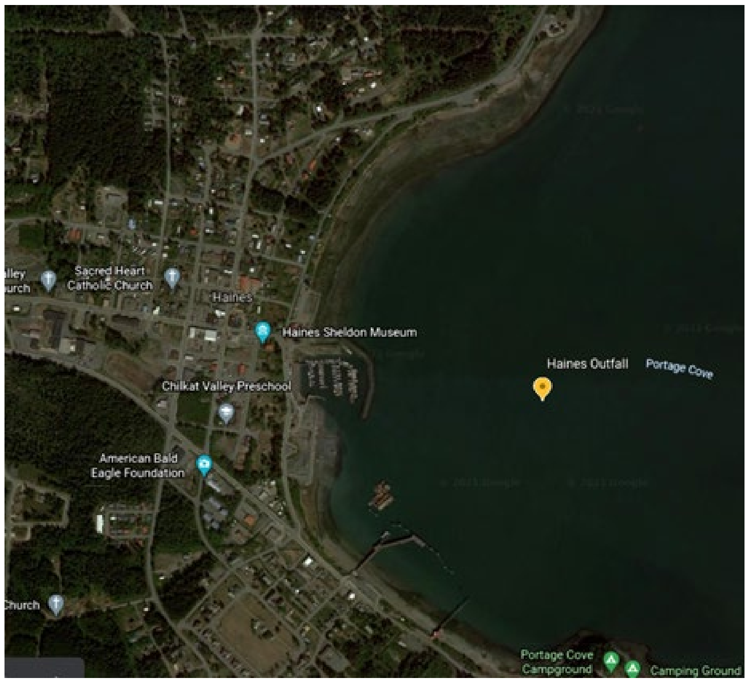

Figure 1. Aerial View of the POTW Outfall Location at Haines

According to the permit fact sheet, the circulation patterns within Portage Cove are not known. The effluent discharged by the Haines WWTP is subject to a net transport of water out of Chinook Inlet due to fresh water supplied by runoff. The period of low net circulation is expected to be December through April, during times of minimum river flow. NOAA 6-minute tidal current predictions from Battery Point, Chinook Inlet (SEA0826) were used to calculate the 10th percentile and average tidal current velocities at 35 and 133 ft. (10.7 and 40.5 m; Table 2), that were then interpolated to the discharge depth of 21.1 m. The resulting 10th percentile current velocity used for modeling was 2.3 cm/s, while the average ebb and flood tidal velocities were 10.5 and 12.6 cm/s.

No specific data were available for vertical profiles of temperature and salinity in Portage Cove or Chinook Inlet. Such data are used to calculate the density profile and define the vertical stratification that limits vertical mixing of the buoyant discharge plume. Instead, we used vertical profiles of temperature and salinity measured in Tiaya Inlet, an adjoining waterway that is also the receiving water body for Skagway's discharge. Vertical profile data were available for five locations that were sampled in October

[9] Mean lower low water.

2002, July and August 2004, and June 2005. Preliminary initial dilution simulations made with UM3 for profiles measured at four of the locations (the fifth was excluded because it was influenced by freshwater input from a tributary near Skagway), determined that the June 2005 vertical profile from site 1 (shown in Figure 2) was limiting in terms of minimizing effluent dilution. That profile was used for all subsequent dilution modeling at Haines.

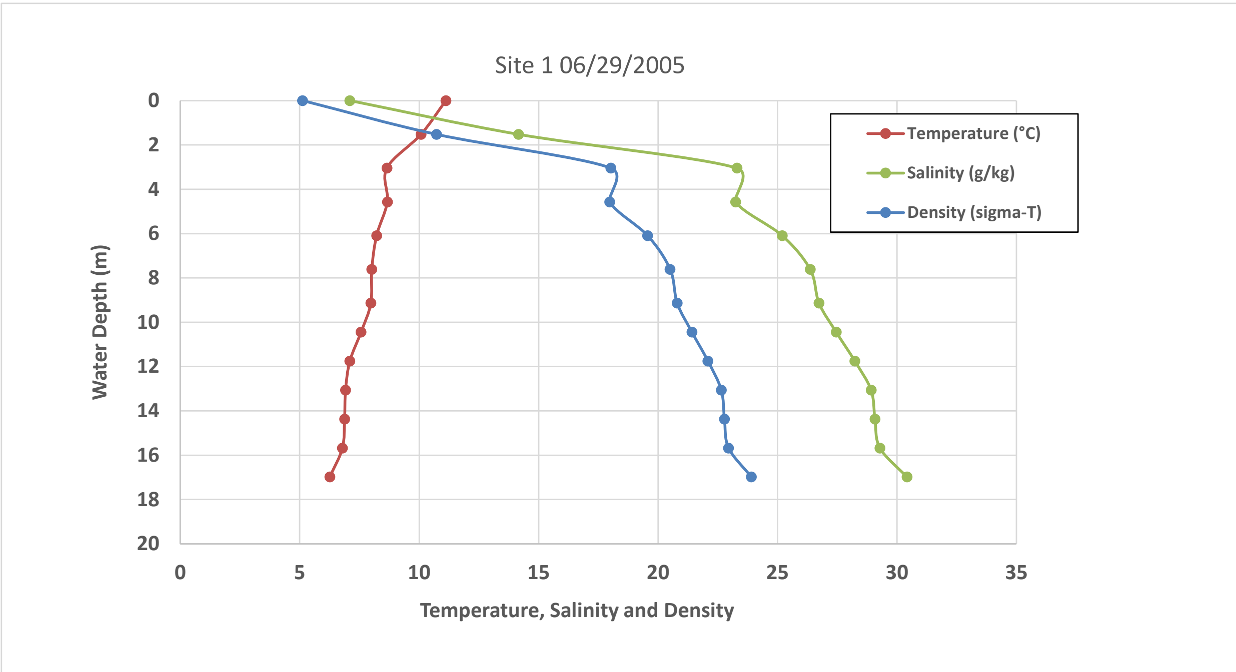

Figure 2. Vertical Ambient Profile of Temperature, Salinity and Density in Haines Mixing Zones Resulting in Least Mixing

Mixing zone dilution modeling results for Haines are summarized in Table 3. The two applicable initial mixing models, UM3 and DKHW, gave nearly identical results for dilution at a distance of 1*depth (Table 3, simulations 10 vs. 11). UM3 was selected for further analysis at Haines. The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Dilution factors at distances of 1*depth to 10*depth range from 100 to 766 (Table 3, simulations 15-18); accounting for bacterial decay had a negligible effect on dilution factors. Graphical examples of the dilution model predictions are presented in Figures 3 (plan view from above of the discharge plume boundary), 4 (profile view from the side of the discharge plume centerline and boundary) and 5 (discharge plume average and centerline dilution vs. distance from the outfall). As shown in Table 3, the plume was trapped at a depth of 20 m by the ambient density stratification, the initial mixing region extended 16 m from the outfall, and the travel time to the mixing zone boundaries ranged from 4 minutes (MZ=1*depth) to 143 minutes (MZ=10*depth). A dilution factor of 99 was predicted for the boundary of the initial mixing region and at the distance to the shore (549 m) the DF was 2770.

The sensitivity of the initial mixing model to a number of inputs (effluent temperature[10], current velocity and direction, and discharge flow rate) is demonstrated in simulations 20-28 (Table 3). Of these

[10] The alternative effluent temperature used for sensitivity analysis was the monthly average effluent temperature for the month found to have the most limited dilution.

parameters, DFs were most sensitive to variation in effluent flow rate (Q), with dilution increasing with greater flow. DFs were relatively insensitive to variation in ambient velocity. Sensitivity of the far-field model to bounding values of the diffusion parameter α (alpha) was also found to have a significant effect on dilution factors, as was substituting the 4/3-power law with linear eddy diffusivity (see Washington DoE, 2018 for explanation).

Table 3. Haines mixing zone dilution modeling results

Model simulation	Ambient Input	Model(s)	MZ Distance (m)	Froude Number	Dilution Factor	Dilution Factor w/Bacteria Decay	Trapping depth (m)	Length of Initial Mixing Region (m)	Travel Time to MZ Boundary (min)[11]
1. MZ=1*depth	Skagway site 1 Oct. 2002	UM3	21.3	190	117	118	17	>21.3	
2. “ “	Skagway site 2 Oct. 2002	UM3	“ “	191	118	118	17	>21.3	
3. “ “	Skagway site 4 Oct. 2002	UM3	“ “	190	117	118	17	>21.3	
4. “ “	Skagway site 1 Jul. 2004	UM3	“ “	189	117	118	17	>21.3	
5. “ “	Skagway site 2 Jul. 2004	UM3/FF	“ “	185	110	113	19	20	2
6. “ “	Skagway site 4 Jul. 2004	UM3/FF	“ “	181	113	116	19	21	0.5
7. “ “	Skagway site 1 Aug. 2004	UM3	“ “	188	118	118	17	>21.3	
8. “ “	Skagway site 2 Aug. 2004	UM3	“ “	186	117	117	17	>21.3	
9. “ “	Skagway site 4 Aug. 2004	UM3/FF	“ “	181	114	117	19	21	0.2
10. “ “	Skagway site 1 June 2005	UM3/FF	“ “	179	99	104	20	16	5
11. “ “	Skagway site 1 June 2005	DKHW/FF	“ “	179	99	99	20	16	4
12. “ “	Skagway site 2 June 2005	UM3/FF	“ “	183	105	109	20	18	2
13. “ “	Skagway site 4 June 2005	UM3	“ “	185	117	117	17	>21.3	

[11] Travel time to MZ boundary was calculated only for distances exceeding length of initial mixing region.

Model simulation	Ambient Input	Model(s)	MZ Distance (m)	Froude Number	Dilution Factor	Dilution Factor w/Bacteria Decay	Trapping depth (m)	Length of Initial Mixing Region (m)	Travel Time to MZ Boundary (min)[11]
Different mixing zone distances:									
14. MZ= initial mixing region	Skagway site 1 June 2005	UM3	16	179	**99**	100	20		1
15. MZ=1*depth	" "	UM3/FF	21.3	179	**100**	100	20	16	4
16. MZ=2*depth	" "	UM3/FF	42.6	179	**136**	137	20	16	19
17. MZ=5*depth	" "	UM3/FF	106.5	179	**330**	331	20	16	65
18. MZ=10*depth	" "	UM3/FF	213	179	**766**	768	20	16	143
19. MZ=distance to nearest shore	" "	UM3/FF	549	179	**2770**	2780	20	16	386
Model sensitivity:									
20. avg. effluent T=11.975° C	Skagway site 1 June 2005	UM3/FF	21.3	181	100	100	20	16	4
21. ½*current v=1.15 cm/s	" "	UM3/FF	" "	178	101	101	20	16	8
22. ¼ *current v=0.575 cm/s		UM3/FF	" "	179	120	120	20	16	16
23. 2*current v=4.6 cm/s	" "	UM3/FF	" "	179	105	105	20	17	2
24. average current v=12.6 cm/s	" "	UM3/FF	" "	179	126	126	20	19	4
25. reverse current direction=270°	" "	UM3/FF	" "	179	92	92	20	15	4
26. average Q=0.27 MGD	" "	UM3/FF	" "	17	63	63	18	5	12
27. Q/2=1.45 MGD	" "	UM3/FF	" "	89	87	87	20	11	7
28. 2*Q=5.8 MGD	" "	UM3	" "	358	111	111	20	21	0.5

Model simulation	Ambient Input	Model(s)	MZ Distance (m)	Froude Number	Dilution Factor	Dilution Factor w/Bacteria Decay	Trapping depth (m)	Length of Initial Mixing Region (m)	Travel Time to MZ Boundary (min)[11]
Far-field model sensitivity to diffusion parameter:									
29. alpha=0.0001	Skagway site 1 June 2005	UM3/FF	213	178	248	249	20	16	143
30. alpha=0.000453	" "	UM3/FF	" "	178	1280	1280	20	16	143
31. Linear eddy diffusivity	" "	UM3/FF	" "	178	486	488	20	16	143

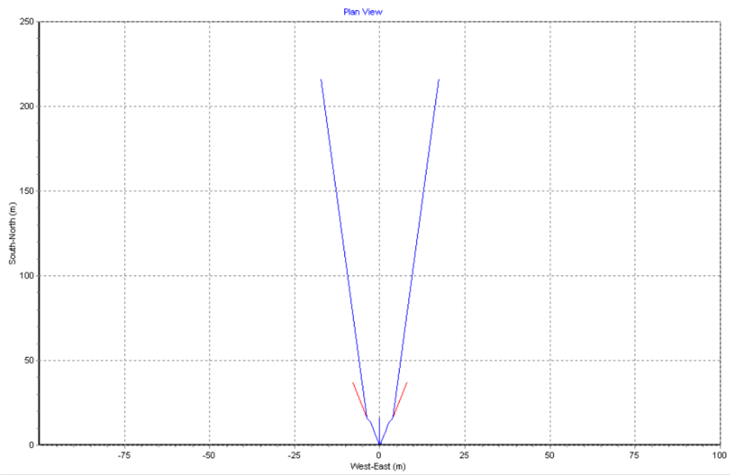

Figure 3. Haines Discharge Plume Boundary Plan View from Above

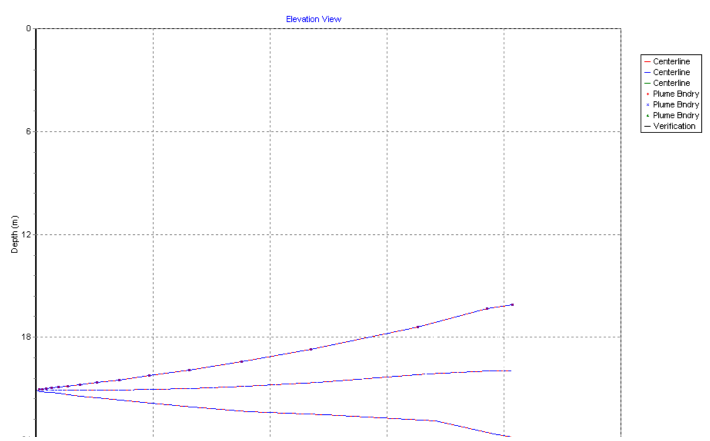

Figure 4. Haines Discharge Plume Centerline and Boundary Profile View from Side

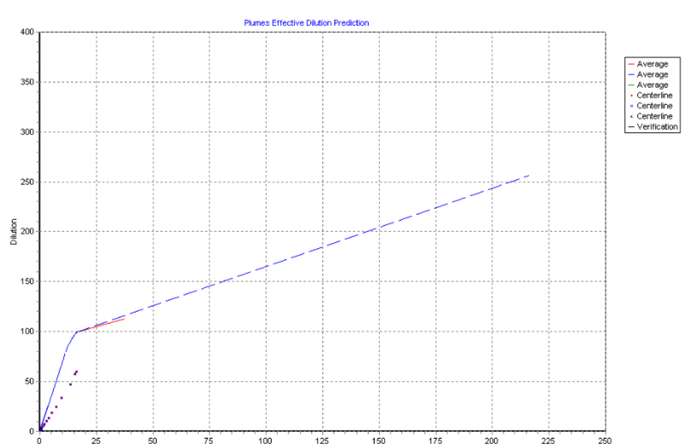

Figure 5. Haines Discharge Plume Average and Centerline Dilution vs. Distance from Outfall

KETCHIKAN

The wastewater treated at Ketchikan is discharged 221 m offshore of Charcoal Point in the Tongass Narrows (Figure 6), at a depth of 29.9 m (MLLW). Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2.

Figure 6. Aerial View of the POTW Outfall Location at Ketchikan

Charcoal Point is at the narrowest width of the Narrows and is approximately 400 m wide and 34 m deep. According to the 2000 Permit application, the Tongass Narrows has a net northwest seaward exchange (away from the City and Pennock Island) with the Gulf of Alaska. Strong currents (that do not vary seasonally) provide vertical mixing in Tongass Narrows, minimizing the vertical density gradient and preventing stratification. Ambient tidal current data were collected with a current meter deployed near shore in December 1988 to verify published Tidal Current Table predictions. The data collected indicate that the flood tide current velocity was 34 cm/s, while the ebb tide currents was 1 cm/s in both directions. NOAA 6-minute tidal current predictions from East of Airport (SEA0711) were used to calculate the 10th percentile and average tidal current velocities at a depth of 87 ft. (26.5 m; Table 2). The 10th percentile current velocity used for modeling was 5.9 cm/s, while the average ebb and flood tidal velocities were 49.2 and 20.1 cm/s.

Preliminary initial dilution simulations made with UM3 for five available ambient profiles, determined that the July 1997 vertical profile from Site 3 (Figure 7) was limiting in terms of minimizing effluent dilution. As noted previously, the diffuser at Ketchikan was a hybrid, consisting of five 6-inch ports on a manifold and a single 12-inch port. These were modeled separately, and initial simulations with both UM3 and DKHW demonstrated that effluent dilution from the single 12-inch port was lower than from the five, 6-inch ports. UM3 gave more conservative dilution predictions (see Table 4, simulations 5 vs. 6), so that initial mixing model was selected for further analysis at Ketchikan.

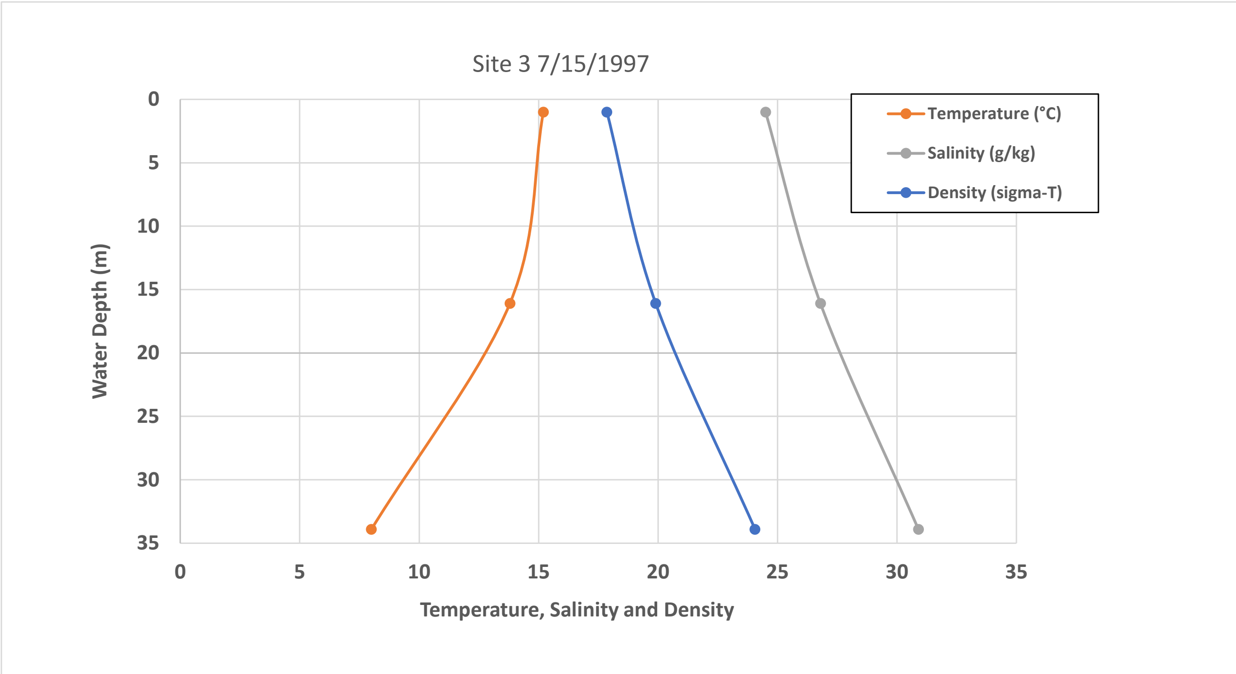

Figure 7. Vertical Ambient Profile of Temperature, Salinity and Density in Ketchikan Mixing Zone Resulting in Least Mixing.

The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Because the nearest shoreline was within ten times the plume diameter (calculated as the 10*depth mixing zone distance), it was assumed to impose a boundary constraint on far-field mixing. Following the guidance of Frick et al. (2010), we based far-field predictions at Ketchikan on the linear eddy diffusivity (LED) parameterization in FARFIELD. Sensitivity of DF predictions to this assumption is shown in Table 4 (simulations 20 vs. 31 and 32).

Dilution factors at distances of 1*depth to 10*depth range from 52 to 179 (Table 4, simulations 17-20). It should be noted that the 10*depth distance (299 m) is greater than the distance from the diffuser to shore (221 m), so it may be appropriate to truncate DF predictions at the distance to shore. Graphical examples of the dilution model predictions are presented in Figures 8 (plan view from above of the discharge plume boundary), 9 (profile view from the side of the discharge plume centerline and boundary) and 10 (discharge plume average and centerline dilution vs. distance from the outfall). Note that these figures include dilution model predictions for both the single 12-inch port and the five 6-inch ports. As shown in Table 4, the plume was trapped at a depth of 22 m by the ambient density stratification, the initial mixing region extended 13 m from the outfall. The travel time to the mixing zone boundaries ranged from 5 minutes (MZ=1*depth) to 81 minutes (MZ=10*depth). A dilution factor of 51 was predicted for the boundary of the initial mixing region and at the distance to the shore (221 m) the DF was 141.

The sensitivity of the initial mixing model to a number of inputs (effluent temperature[12], current velocity and direction, and discharge flow rate) is demonstrated in simulations 22-30 (Table 4). Of these parameters, DFs were most sensitive to variation in ambient velocity (simulations 23-26).

[12] The alternative effluent temperature used for sensitivity analysis was the average of maximum monthly effluent temperatures (no monthly averages in DMR).

Table 4. Ketchikan Mixing Zone Dilution Modeling Results

Model simulation	Ambient input	Model(s)	MZ distance (m)	Diffuser port(s)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)
1. MZ=1*depth	Ketchikan 2000	UM3/FF	29.9	12" port	14	73	75	19	15	4
2. " "	" "	UM3(half spacing)/FF	" "	5x6" ports	18	117	123	22	12	5
3. " "	Ketchikan Pier 12/1988	UM3/FF	" "	12" port	14	158	168	7	17	4
4. " "	" "	UM3(half spacing)/FF	" "	5x6" ports	18	305	324	8	18	3
5. " "	Ketchikan site 3 7/1997	UM3/FF	" "	12" port; limiting	14	52	54	22	13	5
6. " "	" "	DKHW/FF	" "	12" port	14	79	79	24	12	5
7. " "	" "	UM3(DS only, 3 ports x7.35")/FF	" "	5x6" ports	17	60	62	23	12	5
8. " "	Ketchikan site 3 9/1997	UM3/FF	" "	12" port	14	99	104	14	15	4
9. " "	Ketchikan site 3 8/1997	UM3/FF	" "	12" port	13	106	112	12	14	4
10. " "	Ketchikan site 3 7/1996	UM3/FF	" "	12" port	13	99	104	14	15	4
11. " "	Ketchikan site 3 8/1996	UM3/FF	" "	12" port	14	79	83	18	15	4

Model simulation	Ambient input	Model(s)	MZ distance (m)	Diffuser port(s)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)
12. " "	Ketchikan site 3 9/1996	UM3/FF	" "	12" port	14	101	106	15	16	4
13. " "	Ketchikan site 3 7/1998	UM3/FF	" "	12" port	14	89	93	16	6	4
14. " "	Ketchikan site 3 8/1998	UM3/FF	" "	12" port	13	112	118	13	17	4
15. " "	Ketchikan site 3 9/1998	UM3/FF	" "	12" port	14	92	97	16	16	4
Linear eddy diffusivity (LED) far-field model and different mixing zone distances:										
16. MZ= initial mixing region	Ketchikan 3 7/1997	UM3	13	12" port	14	**51**	52	22		1
17. MZ=1*depth	Ketchikan 3 7/1997	UM3/FF-LED	29.9	" "	14	**52**	52	22	13	5
18. MZ=2*depth	" "	" "	59.8	" "	14	**62**	63	22	13	13
19. MZ=5*depth	" "	" "	149.5	" "	14	**105**	106	22	13	39
20. MZ=10*depth	" "	" "	299[13]	" "	14	**179**	180	22	13	81
21. MZ=distance to nearest shore	" "	" "	221	" "	14	**141**	141	22	13	59
Model sensitivity:										
22. avg. effluent T=14.6° C	Ketchikan 3 7/1997	UM3/FF-LED	29.9	12" port	14	52	52	22	13	5

[13] Distance is greater than the distance from the diffuser to shore.

Model simulation	Ambient input	Model(s)	MZ distance (m)	Diffuser port(s)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)
23. ½*current v=2.95 cm/s	" "	" "	" "	" "	14	54	54	20	13	10
24. ¼ *current v=1.475 cm/s	" "	" "	" "	" "	14	67	67	20	13	19
25. 2*current v=11.8 cm/s	" "	" "	" "	" "	14	88	88	24	14	2
26. average current v=49.2 cm/s	" "	UM3	" "	" "	14	179	180	27	30	1
27. reverse current direction=320°	" "	UM3/FF-LED	" "	" "	14	47	47	22	10	6
28. Q/4=0.864 MGD	" "	" "	" "	" "	4	72	72	22	6	7
29. Q/2=1.728 MGD	" "	" "	" "	" "	7	58	59	22	8	6
30. 2*Q=6.912 MGD	" "	" "	" "	" "	28	56	57	23	20	3
Far-field model sensitivity to diffusion parameter:										
31. alpha=0.0001	Ketchikan 3 7/1997	UM3/FF	299	12" port	14	94	94	22	13	81
32. alpha=0.000453	" "	" "	" "	" "	14	396	398	22	13	81

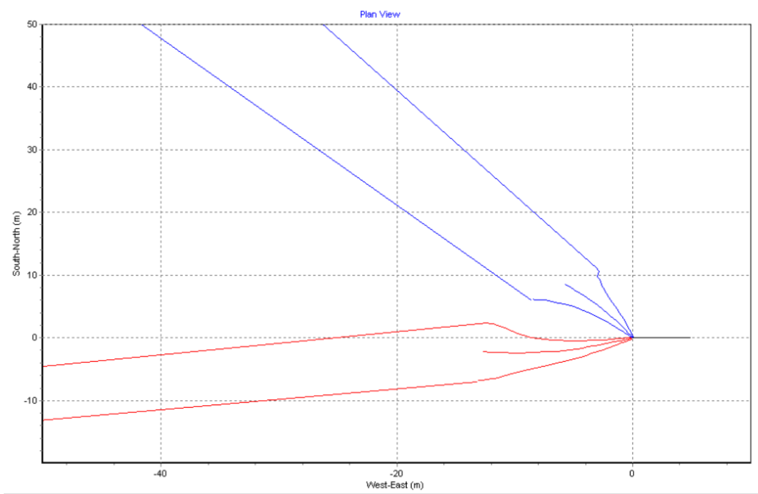

Figure 8. Ketchikan Discharge Plume Boundary Plan View from Above
(plume from 12-inch port is red; plume from five 6-inch ports is blue)

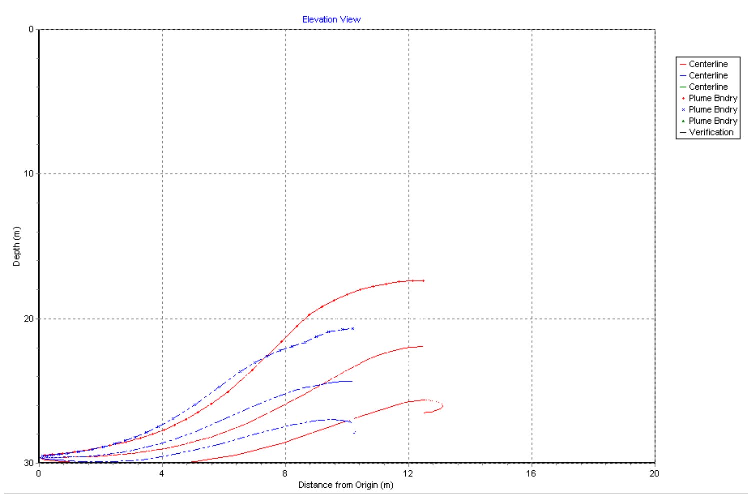

Figure 9. Ketchikan Discharge Plume Centerline and Boundary Profile View from Side

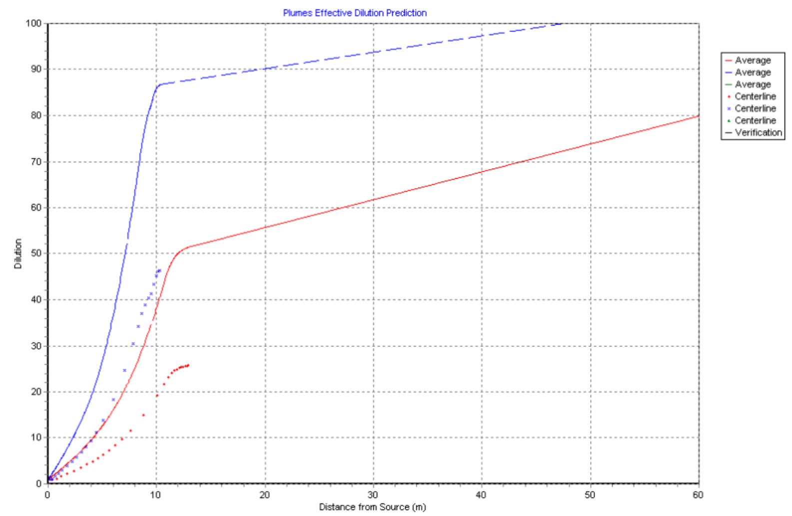

Figure 10. Ketchikan discharge plume average and centerline dilution vs. distance from outfall
Figure is based on graphic output by VP; DFs in far field (beyond 13 m for the 12-inch port) are overestimated because VP assumes 4/3-power law instead of linear eddy diffusivity.

PETERSBURG

Wastewater treated at Petersburg is discharged 366 m offshore in Frederick Sound (Figure 11), from a two-port diffuser at a depth of 18.3 m (MLLW). The permitted maximum flow is 3.6 MGD. Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2. The port spacing at Petersburg is uncertain (somewhere in the range of 10 to 34 ft.) due to only two of five diffuser ports being open. The models predicted lower DFs for the narrowest port spacing (10 ft.), so that spacing was used for all model simulations.

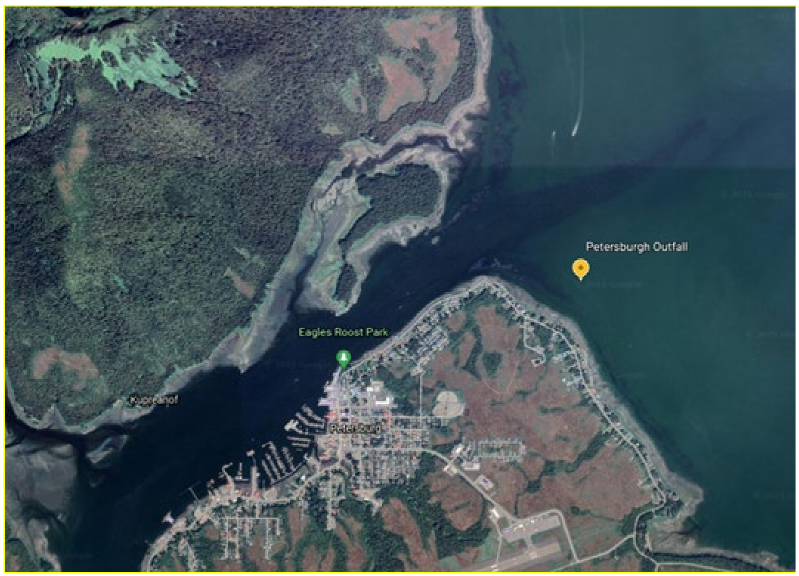

Figure 11. Aerial View of the POTW Outfall Location at Petersburg

Frederick Sound is connected to the Pacific Ocean via Chatham Strait to the northwest and Dry Strait/Sumner Strait to the southeast. According to the 1990 permit questionnaire, surface water densities near the outfall vary due to freshwater inputs from nearby streams. Maximum freshwater input to Frederick Sound occurs in summer (June or July) and minimum freshwater input occurs in March. The freshwater input is due primarily to the combined flows of the Stikine and Iskut Rivers. Currents generally flow northwestward in Frederick Sound with southwestward flows during large tides. NOAA tidal current predictions for nearby Cosmos Point (PCT3811) were used to calculate the 10th percentile current velocity used for modeling, 1.6 cm/s, and the average ebb and flood tidal velocities, 10.4 and 7.8 cm/s. According to the questionnaire, current velocities in the area are reportedly in the range of two to five knots (100 to 260 cm/s), 10 to 100 times larger than the velocities calculated from NOAA tidal current predictions and used for modeling. This discrepancy in the magnitude of ambient velocities could not be resolved given the information available, but may warrant further inquiry.

Preliminary initial dilution simulations made with UM3 for eight available ambient profiles sampled at two ZID boundary monitoring locations in January of 2002 and 2004, and August 2003 and 2005, determined that the August 2005 vertical profile from Site 1 (Figure 12) was limiting in terms of minimizing effluent dilution.

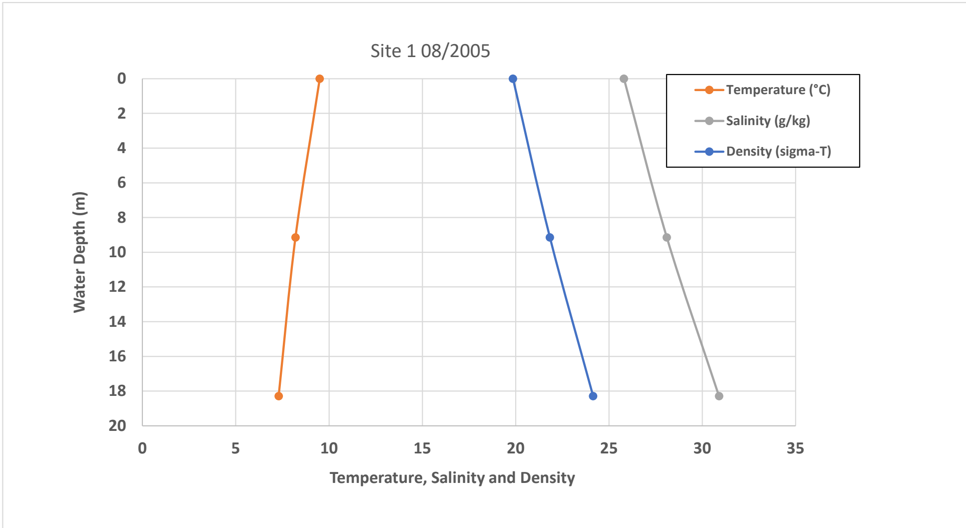

Figure 12. Vertical Ambient Profile of Temperature, Salinity and Density in Petersburg Mixing Zone Resulting in Least Mixing

Mixing zone dilution modeling results for Petersburg are summarized in Table 5. The two applicable initial mixing models, UM3 and DKHW, gave very similar results for dilution at a distance of 1*depth (67 vs. 70). UM3 gave slightly more conservative dilution predictions, so that initial mixing model was selected for further analysis at Petersburg. The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Dilution factors at distances of 1*depth to 10*depth range from 67 to 647 (Table 5, simulations 11-14); accounting for bacterial decay had a negligible effect on dilution factors. Graphical examples of the dilution model predictions are presented in Figures 13 (plan view from above of the discharge plume boundary), 14 (profile view from the side of the discharge plume centerline and boundary) and 15 (discharge plume average and centerline dilution vs. distance from the outfall). As shown in Table 5, the plume was trapped at a depth of 14 m by the ambient density stratification, the initial mixing region extended 23 m from the outfall, and the travel time to the mixing zone boundaries ranged from 1 minute (MZ=1*depth) to 167 minutes (MZ=10*depth). A dilution factor of 74 was predicted for the boundary of the initial mixing region and at the distance to the shore (366 m) the DF was 1720.

The sensitivity of the initial mixing model to a number of inputs (effluent temperature, current velocity and direction, and discharge flow rate) is demonstrated in simulations 16-24 (Table 5). DFs were moderately sensitive to variation in ambient velocity (DFs increase with velocity, simulations 17-19) and effluent flow rate (DFs decrease with Q, simulations 21-24). Sensitivity of the far-field model to bounding values of the diffusion parameter α (alpha) was also found to have a significant effect on dilution factors, as was substituting the 4/3-power law with linear eddy diffusivity.

Table 5. Petersburg Mixing Zone Dilution Modeling Results

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[14]
1. MZ=1*depth	Petersburg 1 8/2005	UM3	18.3	114	67	67	15	>18.3	
2. " "	" "	DKHW	18.3	114	70	70	14	>18.3	
3. " "	Petersburg 1 8/2003	UM3	18.3	95	72	73	12	>18.3	
4. " "	Petersburg 1 1/2002	UM3	18.3	114	69	69	14	>18.3	
5. " "	Petersburg 2 1/2002	UM3	18.3	113	69	69	14	>18.3	
6. " "	Petersburg 1 1/2004	UM3	18.3	114	69	69	14	>18.3	
7. " "	Petersburg 2 1/2004	UM3	18.3	114	69	69	14	>18.3	
8. " "	Petersburg 2 8/2003	UM3	18.3	94	72	72	12	>18.3	
9. " "	Petersburg 2 8/2005	UM3	18.3	116	68	68	15	>18.3	
Dilution at different distances:									
10. MZ= initial mixing region	Petersburg 1 8/2005	UM3	23	115	**74**	75	14		1
11. MZ=1*depth	" "	UM3	18.3	115	**67**	67	15	>18.3	1
12. MZ=2*depth	" "	UM3/FF	36.6	115	**90**	90	14	23	15
13. MZ=5*depth	" "	UM3/FF	91.5	115	**256**	257	14	23	72
14. MZ=10*depth	" "	UM3/FF	183	115	**647**	650	14	23	167
15. MZ=distance to nearest shore	" "	UM3/FF	366	115	**1720**	1730	14	23	358

[14] Travel time to MZ boundary was calculated only for distances exceeding length of initial mixing region.

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[14]
Model sensitivity:									
16. avg. effluent T=13.2° C	Petersburg 1 8/2005	UM3	18.3	115	67	68	15	>18.3	
17. ½*current v=0.8 cm/s	“ “	UM3	18.3	115	66	66	15	>18.3	
18. 2*current v=3.2 cm/s	“ “	UM3	18.3	115	70	70	15	>18.3	
19. average current v=10.4 cm/s	“ “	UM3	18.3	115	80	81	16	>18.3	
20. reverse current direction=300°	“ “	UM3	18.3	115	66	66	15	>18.3	
21. average Q=0.43 MGD	“ “	UM3/FF	18.3	14	81	82	12	6	13
22. Q/4=0.9 MGD	“ “	UM3/FF	18.3	29	68	69	13	9	9
23. Q/2=1.8 MGD	“ “	UM3/FF	18.3	57	65	65	14	15	4
24. 2*Q=7.2 MGD	“ “	UM3	18.3	229	65	65	17	>18.3	
Far-field model sensitivity to diffusion parameter:									
25. alpha=0.0001	Petersburg 1 8/2005	UM3/FF	183	114	202	203	14	23	167
26. alpha=0.000453	“ “	UM3/FF	183	114	1090	1091	14	23	167
27. Linear eddy diffusivity	“ “	UM3/FF	183	114	397	399	14	23	167

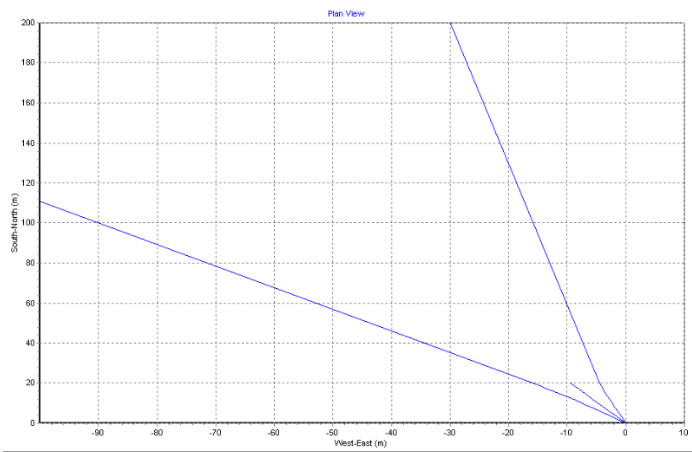

Figure 13. Petersburg Discharge Plume Boundary Plan View from Above

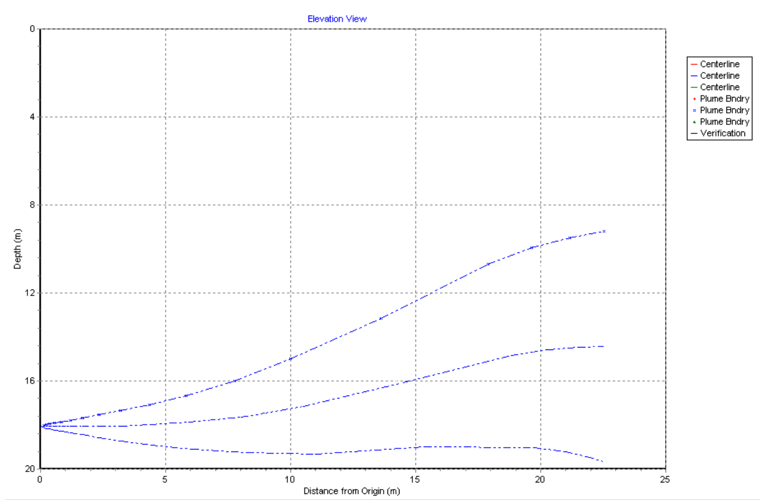

Figure 14. Petersburg Discharge Plume Centerline and Boundary Profile View from Side

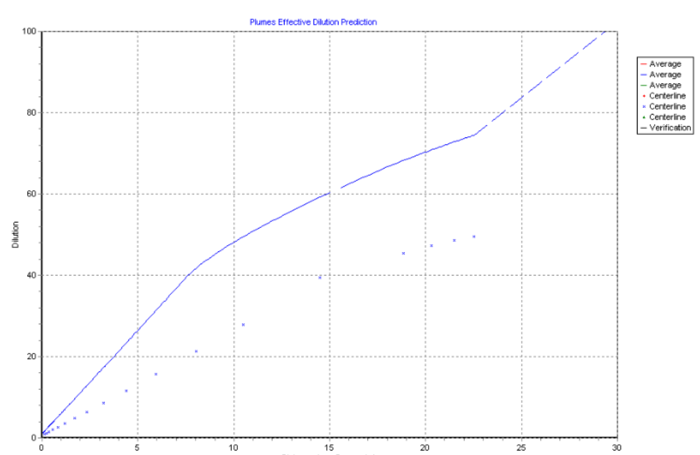

Figure 15. Petersburg Discharge Plume Average and Centerline Dilution vs. Distance from Outfall

SITKA

The wastewater treated at Sitka is discharged 114 m offshore in the Middle Channel of Sitka Sound (Figure 16), from a 16-port diffuser at a depth of 24.4 m (MLLW). The permitted maximum flow is 5.3 MGD.

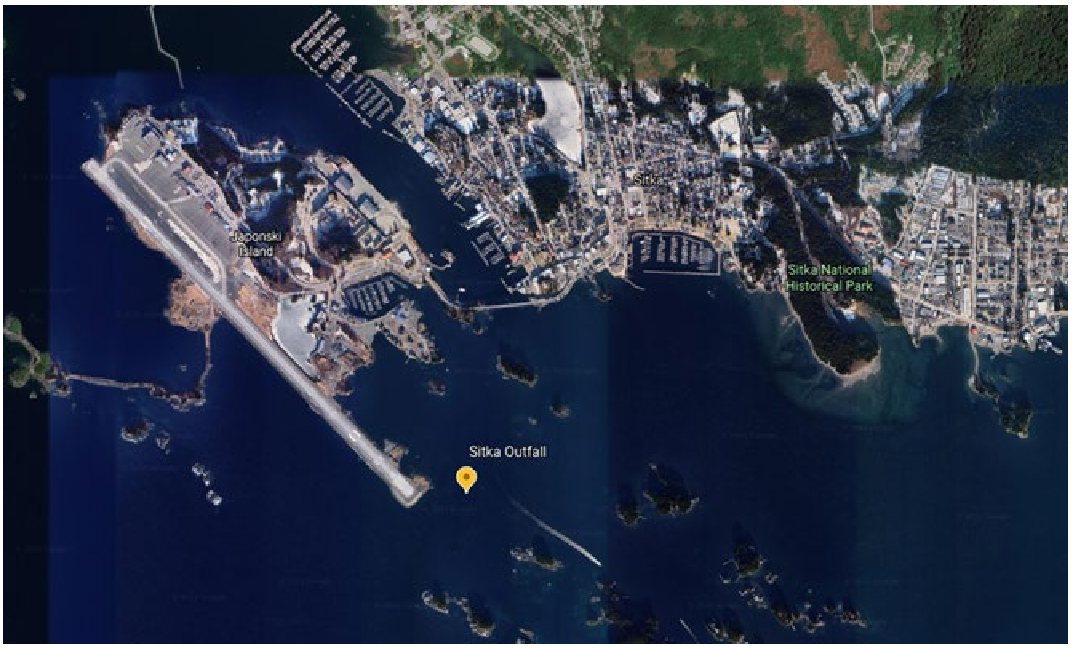

Figure 16. Aerial View of the POTW Outfall Location at Sitka

According to the permit fact sheet, the Middle Channel has relatively weak tidal currents, rotating in a clockwise pattern, which are superimposed on the seaward flow of fresh water in Sitka Sound. The net current is toward the southeast and included an easterly wind-driven component. The direction of transport of effluent from the outfall varies, depending upon the tidal stage and direction of prevailing winds. NOAA tidal current predictions for Sitka Harbor, Channel off Harbor Island (PCT4166) were used to calculate the 10^{th} percentile current velocity used for modeling, 1.7 cm/s, and the average ebb and flood tidal velocities, 10.3 and 8.0 cm/s.

Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2. Detailed vertical ambient profiles were only available for one location (Site C, a reference station west of the outfall) that was in sampled in the months of April and July in 2010 and 2015. Preliminary initial dilution simulations made with UM3 for these four available ambient profiles, determined that the July 2010 vertical profile from Site C (Figure 17) was limiting in terms of minimizing effluent dilution (Table 6, simulations 1, 2, 8 and 9).

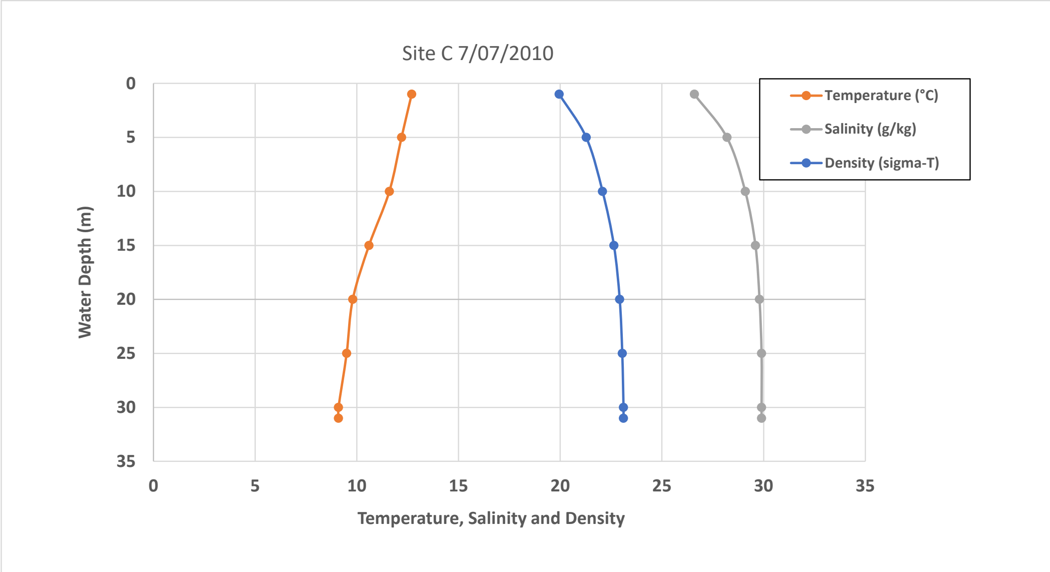

Figure 17. Vertical Ambient Profile of Temperature, Salinity and Density in Sitka Mixing Zone Resulting in Least Mixing

Mixing zone dilution modeling results for Sitka are summarized in Table 6. The two initial mixing models, DKHW and UM3, combined with the Brooks far-field model gave similar results for dilution at a distance of 1*depth (sims. 2 and 5); simulation results for the downstream-only cross-diffuser merging approach and the third initial mixing model, NRFIELD, also fell within this range of DFs. DKHW gave slightly more conservative dilution predictions, so that initial mixing model was selected for further analysis at Sitka.

The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Because the nearest shoreline was within ten times the plume diameter (calculated as the 10*depth mixing zone distance), it was assumed to impose a boundary constraint on far-field mixing. Following the guidance of Frick et al. (2010), we based far-field predictions at Sitka on the linear eddy diffusivity (LED) parameterization in FARFIELD. Sensitivity of DF predictions to this assumption is shown in Table 6 (simulations 14 vs. 25 and 26).

Dilution factors at distances of 1*depth to 10*depth range from 87 to 227 (Table 6, simulations 11-14); accounting for bacterial decay had a negligible effect on dilution factors. It should be noted that the 5*depth and 10*depth distances (122 and 244 m) are greater than the distance from the diffuser to shore (114 m), so it may be appropriate to truncate DF predictions at the distance to shore. Graphical examples of the dilution model predictions are presented in Figures 18 (plan view from above of the discharge plume boundary), 19 (profile view from the side of the discharge plume centerline and boundary) and 20 (discharge plume average and centerline dilution vs. distance from the outfall). As shown in Table 6, the plume was trapped at a depth of 10 m by the ambient density stratification, the initial mixing region extended 6.9 m from the outfall, and the travel time to the mixing zone boundaries ranged from 17 minutes (MZ=1*depth) to 232 minutes (MZ=10*depth). A dilution factor of 86 was predicted for the boundary of the initial mixing region and at the distance to the shore (114 m) the DF was 138.

The sensitivity of the initial mixing model to a number of inputs (effluent temperature, current velocity and direction, and discharge flow rate) is demonstrated in simulations 16-24 (Table 6). DFs were moderately sensitive to variation in ambient velocity (DFs increase with velocity, simulations 17-19) and effluent flow rate (DFs decrease with Q, simulations 22-24).

Table 6. Sitka Mixing Zone Dilution Modeling Results

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[15]
1. MZ=1*depth	Sitka C 7/2015	UM3(half spacing)/FF	24.4	11	131	133	9	7	17
2. " "	Sitka C 7/2010	" "	24.4	12	118	119	12	6	18
3. " "	Sitka C 7/2010	" "	16.0	12	113	114	12	6	10
4. " "	Sitka C 7/2010	NRFIELD	16.0	12	89		10		
5. " "	Sitka C 7/2010	DKHW(half spacing)/FF	24.4	12	87	87	10	7	17
6. " "	" ";	UM3(DS-only, 8 portsx5.3")/FF	24.4	11	109	110	11	7	17
7. " "	" "	DKHW(DS-only, 8 portsx5.3")/FF	24.4	11	90	90	10	8	16
8. " "	Sitka C 4/2010	UM3(half-spacing)/FF	24.4	12	179	181	4	7	17
9. " "	Sitka C 4/2015	" "	24.4	11	172	174	5	7	17
Linear eddy diffusivity (LED) far-field model and different mixing zone distances:									
10. MZ= initial mixing region	Sitka C 7/2010	DKHW(half-spacing)	6.9	12	**86**	86			1
11. MZ=1*depth	" "	DKHW(half-spacing)/FF-LED	24.4	12	**87**	87	10	7	17
12. MZ=2*depth	" "	" "	48.8	12	**97**	97	10	7	41
13. MZ=5*depth	" "	" "	122[16]	12	**143**	143	10	7	113
14. MZ=10*depth	" "	" "	244[16]	12	**227**	227	10	7	232

[15] Travel time to MZ boundary was calculated only for distances exceeding length of initial mixing region.
[16] Distance is greater than the distance from the diffuser to shore.

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[15]
15. MZ=distance to nearest shore	" "	" "	114	12	**138**	138	10	7	105
Model sensitivity:									
16. avg. effluent T=14° C	Sitka C 7/2010	DKHW(half-spacing)/FF-LED	24.4	12	87	87	10	7	17
17. ½*current v=0.85 cm/s	" "	" "	" "	12	79	79	9	7	35
18. 2*current v=3.4 cm/s	" "	" "	" "	12	119	119	11	9	8
19. average current v=10.3cm/s	" "	" "	" "	12	187	187	15	22	0.5
20. reverse current direction=45°	" "	" "	" "	12	87	87	10	7	17
21. current dir +30°	" "	" "	" "	12	131	131	12	7	17
22. average Q=0.98 MGD	" "	" "	" "	2	208	208	15	4	20
23. Q/2=2.65 MGD	" "	" "	" "	6	121	121	12	5	19
24. 2*Q=10.6 MGD	" "	" "	" "	23	66	66	8	12	12
Far-field model sensitivity to diffusion parameter:									
25. alpha=0.0001	Sitka C 7/2010	DKHW(half-spacing)/FF	244	12	126	126	10	7	233
26. alpha=0.000453	" "	" "	" "	12	426	426	10	7	233

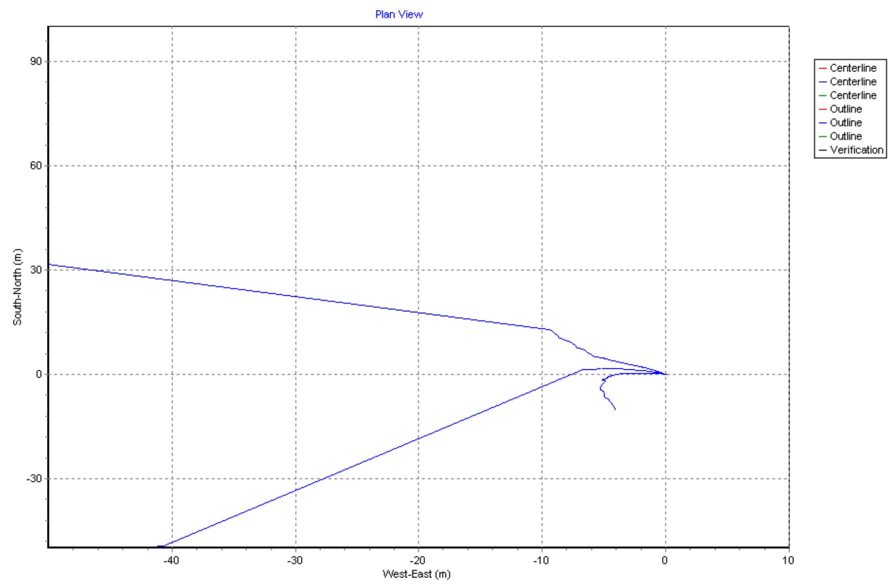

Figure 18. Sitka Discharge Plume Boundary Plan View from Above

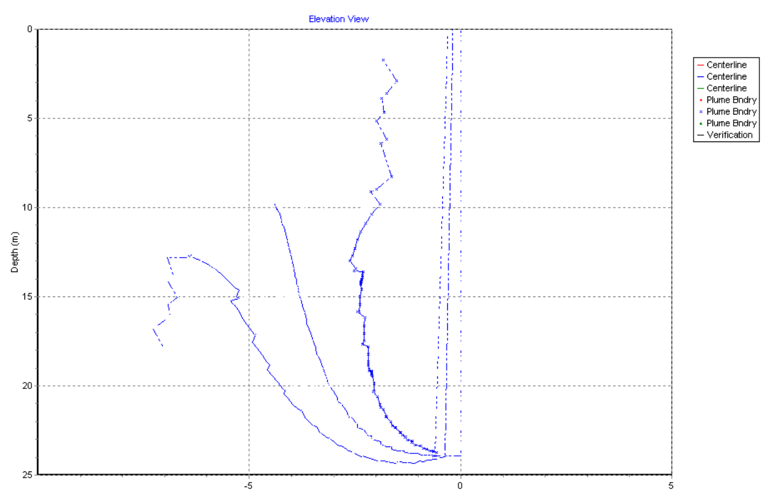

Figure 19. Sitka Discharge Plume Centerline and Boundary Profile View from Side

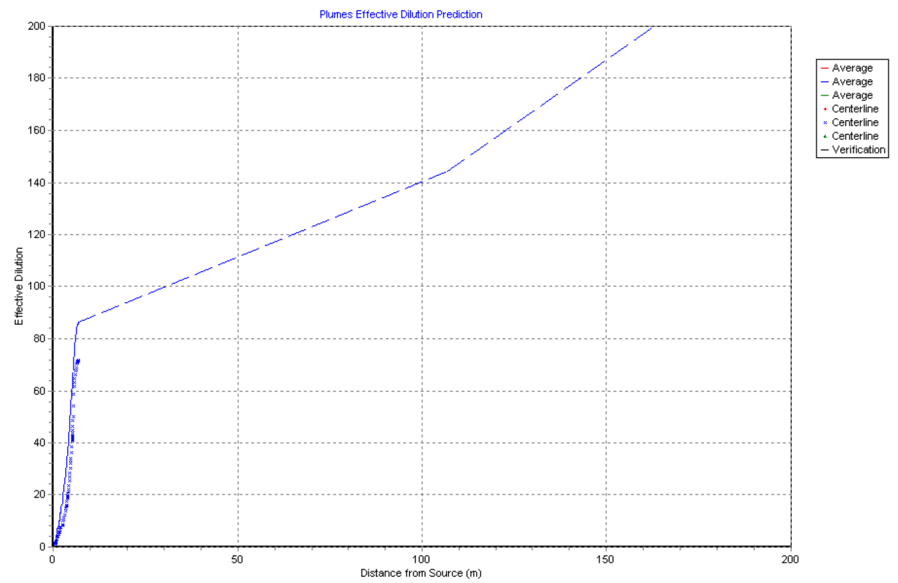

Figure 20. Sitka Discharge Plume Average and Centerline Dilution vs. Distance from Outfall (Figure is based on graphic output by VP; DFs in far field (beyond 7 m) are overestimated because VP assumes 4/3-power law instead of linear eddy diffusivity).

SKAGWAY

Wastewater treated at Skagway is discharged 125 m offshore in Tiaya Inlet (Figure 21), at a depth of 18.3 m (MLLW), from an 8-port diffuser. The permitted maximum flow rate is 0.63 MGD.

Figure 21. Aerial View of the POTW Outfall Location at Skagway

According to the permit fact sheet, Taiya Inlet is a deep fjord with a 457 m average depth. Taiya Inlet supports a classic fjord-type, two-layer circulation, with a large saline lower layer and a very thin upper brackish layer. The circulation of the inlet is dependent on tides and freshwater flow into the inlet. There are no obstructions to impede circulation near the outfall. Stratification in Taiya Inlet is dependent on freshwater inflows from the Taiya and Skagway Rivers with the highest stratification typically occurs during the high runoff summer period from June through August. As noted in the 2007 permit reapplication, a small cross-current (2 cm/s) was present under stratified condition in a June 1999 temperature/salinity data set.

NOAA 6-minute tidal current predictions from Tiaya Inlet (SEA0825) were used to calculate the 10th percentile and average tidal current velocities (Table 2). The 10th percentile current velocity used for modeling was 1.4 cm/s, while the average ebb and flood tidal velocities were 6.9 and 12.2 cm/s.

Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2. Vertical profiles of temperature and salinity measured in Tiaya Inlet were available for five locations that were sampled in October 2002, July and August 2004 and June 2005. Preliminary initial dilution simulations made with UM3 for all available profiles, determined that the June 2005 vertical profile measured at site 1 (shown in Figure 22) was limiting in terms of minimizing effluent dilution[17]. That profile was used for all subsequent dilution modeling at Skagway.

[17] A different vertical profile measured in June 2005 at site 5 (a site in the cruise ship terminal harbor nearest to freshwater inflow from the Skagway River) actually produced smaller DF predictions. However, the unusually low

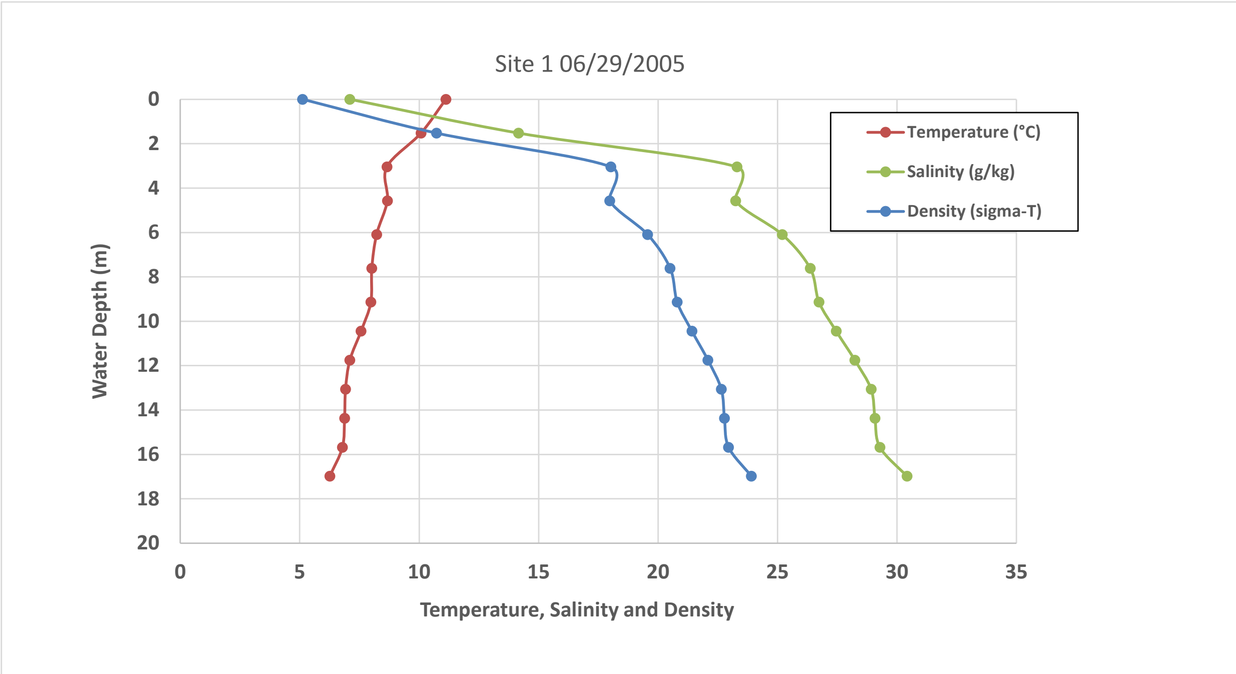

Figure 22. Vertical Ambient Profile of Temperature, Salinity and Density in Skagway Mixing Zone Resulting in Least Mixing

Mixing zone dilution modeling results for Skagway are summarized in Table 7. Two of the applicable initial mixing models, UM3 and DKHW, gave similar results for dilution at a distance of 1*depth, for both cross-diffuser merging approaches (simulations 11-13). UM3 gave slightly more conservative dilution predictions, so that initial mixing model was selected for further analysis at Skagway. We also applied the third initial mixing model, NRFIELD, that predicted DFs reasonably comparable to UM3 (simulations 14 vs. 15) at a distance shorter than 1*depth (5.9 m).

The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Because the nearest shoreline was within ten times the plume diameter (calculated as the 10*depth mixing zone distance), it was assumed to impose a boundary constraint on far-field mixing. Following the guidance of Frick et al. (2010), we based far-field predictions at Skagway on the linear eddy diffusivity (LED) parameterization in FARFIELD. Sensitivity of DF predictions to this assumption is shown in Table 7 (simulations 23 vs. 33 and 34).

Dilution factors at distances of 1*depth to 10*depth range from 56 to 330 (Table 7, simulations 20-23); accounting for bacterial decay had a negligible effect on dilution factors. It should be noted that the 10*depth distance (183 m) is greater than the distance from the diffuser to shore (125 m), so it may be appropriate to truncate DF predictions at the distance to shore. Graphical examples of the dilution model predictions are presented in Figures 23 (plan view from above of the discharge plume boundary), 24

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salinity of the upper 3-4 m of that profile led to difficulties in modeling dilution over the range of parameters and conditions of interest, so the site 1 June 2005 profile (that was the next most conservative in terms of limiting DFs) was used instead.

(profile view from the side of the discharge plume centerline and boundary) and 25 (discharge plume average and centerline dilution vs. distance from the outfall). As shown in Table 7, the plume was trapped at a depth of 15 m by the ambient density stratification, the initial mixing region extended 3.5 m from the outfall, and the travel time to the mixing zone boundaries ranged from 18 minutes (MZ=1*depth) to 214 minutes (MZ=10*depth). A dilution factor of 42 was predicted for the boundary of the initial mixing region and at the distance to the shore (125 m) the DF was 233.

The sensitivity of the initial mixing model to a number of inputs (effluent temperature, current velocity and direction, and discharge flow rate) is demonstrated in simulations 25-32 (Table 7). DFs were moderately sensitive to variation in ambient velocity (minimum DFs at velocities near 2 cm/s, simulations 26-28) and effluent flow rate (DFs decrease with Q, simulations 30-32).

Table 7. Skagway Mixing Zone Dilution Modeling Results

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)
1. MZ=1*depth	Skagway site 1 10/02	UM3 (half spacing) /FF	18.3	10	129	130	9	4	17
2. " "	Skagway site 2 10/02	" "	18.3	10	145	147	7	5	16
3. " "	Skagway site 4 10/02	" "	18.3	10	127	128	9	4	17
4. " "	Skagway site 1 7/2004	" "	18.3	10	94	95	12	4	18
5. " "	Skagway site 2 7/2004	" "	18.3	10	97	97	12	4	17
6. " "	Skagway site 4 7/2004	" "	18.3	10	79	79	13	4	17
7. " "	Skagway site 1 8/2004	" "	18.3	10	130	131	9	4	17
8. " "	Skagway site 2 8/2004	" "	18.3	10	113	114	10	4	17
9. " "	Skagway site 4 8/2004	" "	18.3	10	82	83	13	4	17
10. " "	Skagway site 1 6/2005	" "	18.3	10	59	59	15	3	18
11. " "	" "	UM3(DS-only, 4x3.95")/FF	18.3	10	59	59	14	5	16
12. " "	" "	DKHW(half spacing)/FF	18.3	10	62	63	16	3	18
13. " "	" "	DKHW(DS-only, 4x3.95")/FF	18.3	10	66	66	15	4	17
14. " "	" "	NRFIELD	5.9	10	39		14		
15. " "	" "	UM3(half spacing) /FF	5.9	10	42	42	15	3	3
16. " "	Skagway site 2 6/2005	" "	18.3	10	80	80	13	4	17
17. " "	Skagway site 4 6/2005	" "	18.3	10	100	100	12	4	17
18. " "	Skagway site 5 6/2005	" "	18.3	9	39	39	16	2	19
Linear eddy diffusivity (LED) far-field model and different mixing zone distances:									
19. MZ= initial mixing region	Skagway site 1 6/2005	UM3(half spacing)	3.5	10	**42**	42	15		0.7

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)
20. MZ=1*depth	" "	UM3(half spacing) /FF-LED	18.3	10	**56**	56	15	3	18
21. MZ=2*depth	" "	" "	36.6	10	**86**	86	15	3	39
22. MZ=5*depth	" "	" "	91.5	10	**177**	178	15	3	105
23. MZ=10*depth	" "	" "	183[18]	10	**330**	331	15	3	214
24. MZ=distance to nearest shore	" "	" "	125	10	**233**	234	15	3	145
Model sensitivity:									
25. avg. effluent T=14.7° C	Skagway site 1 6/2005	UM3(half spacing) /FF-LED	18.3	10	56	56	15	3	18
26. ½*current v=0.7 cm/s	" "	" "	" "	10	76	76	15	3	36
27. 2*current v=2.8 cm/s	" "	" "	" "	10	52	52	15	4	9
28. average current v=12.2 cm/s	" "	" "	" "	10	101	101	17	6	2
29. reverse current direction=170°	" "	" "	" "	10	56	56	14	5	19
30. average Q=0.27 MGD				4	73	73	15	2	19
31. Q=0.5 MGD	" "	" "	" "	8	60	60	15	3	18

[18] Distance is greater than the distance from the diffuser to shore.

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)
32. 2*Q=1.26 MGD	" "	" "	" "	20	49	49	15	5	16
Far-field model sensitivity to diffusion parameter:									
33. alpha=0.0001	Skagway site 1 6/2005	UM3(half spacing) /FF	183	10	173	174	15	3	214
34. alpha=0.000453	" "	" "	183	10	1100	1103	15	3	214

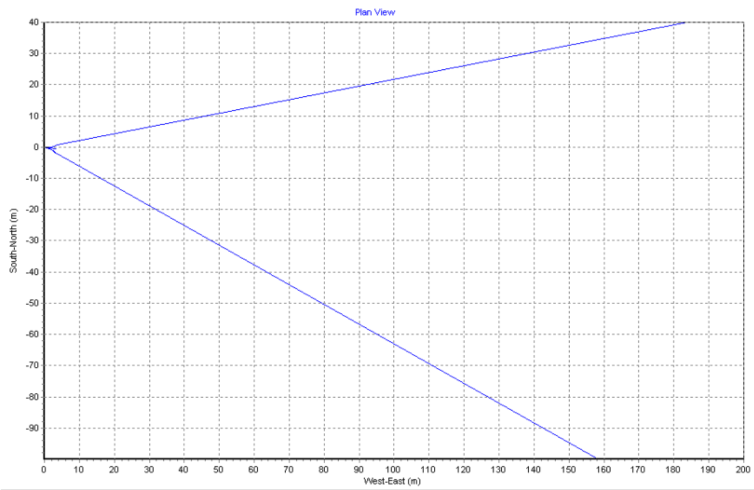

Figure 23. Skagway Discharge Plume Boundary Plan View from Above

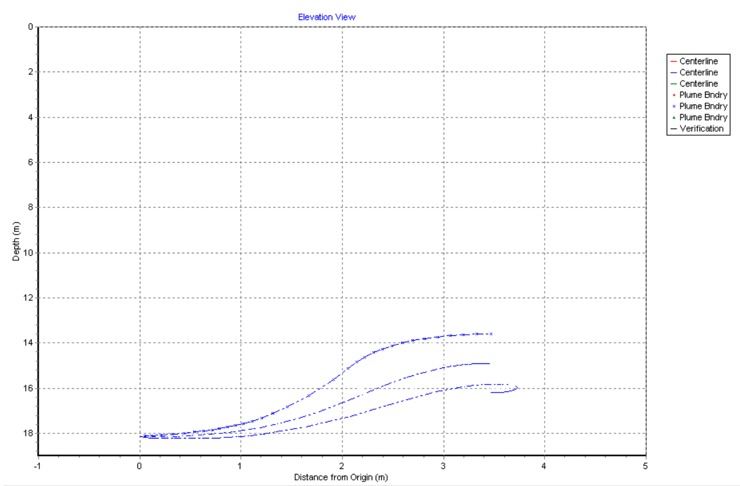

Figure 24. Skagway Discharge Plume Centerline and Boundary Profile View from Side

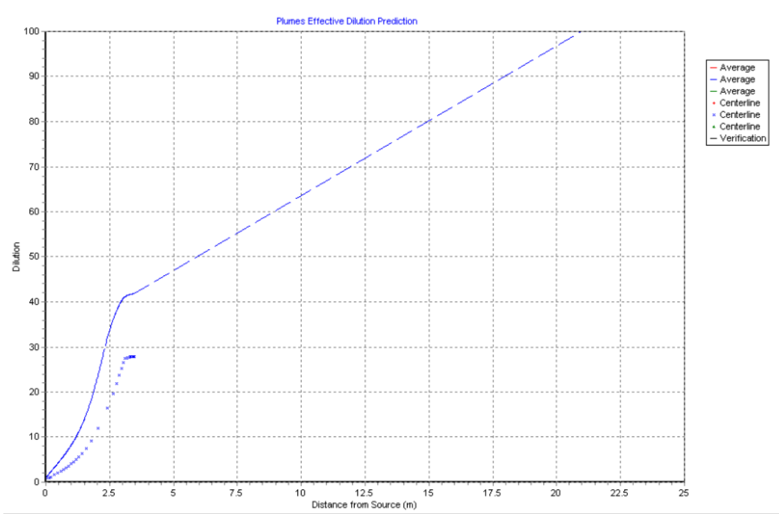

Figure 25. Skagway Discharge Plume Average and Centerline Dilution vs. Distance from Outfall
(Figure is based on graphic output by VP; DFs in far field (beyond 3 m) are overestimated because VP assumes 4/3-power law instead of linear eddy diffusivity)

WRANGELL

The wastewater treated at Wrangell is discharged 457 m offshore in the Zimovia Strait (Figure 26), at a depth of 30.5 m (MLLW), from a 16-port diffuser. The permitted maximum flow rate is 3.0 MGD.

Figure 26. Aerial View of the POTW Outfall Location at Wrangell

According to the permit fact sheet, Zimovia Strait has a net northwest seaward exchange with the Gulf of Alaska. The maximum current velocity is around 51.4 cm/sec (1.0 knot) and the water circulation patterns do not vary seasonally. Strong currents provide vertical mixing, minimize the vertical density gradient, and prevent stratification. Also, according to the permit fact sheet, prior dilution modeling in Zimovia Strait used a conservative current speed of 2.35 cm/sec and no stratification. NOAA tidal current predictions for Wrangell Harbor (PCT3131) were used to calculate the 10th percentile current velocity used for modeling, 4.0 cm/s, and the average ebb and flood tidal velocities, 20.8 and 23.5 cm/s.

Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2. Vertical profiles of temperature and salinity measured in Zimovia strait at the ZID boundaries were available for two mixing zone locations that were sampled in August of 2015, 2016 and 2017. Preliminary initial dilution simulations made with UM3 for all profiles, determined that the vertical profile measured at station 4 in August of 2016 (shown in Figure 27) was limiting in terms of minimizing effluent dilution. That profile was used for all subsequent dilution modeling at Wrangell.

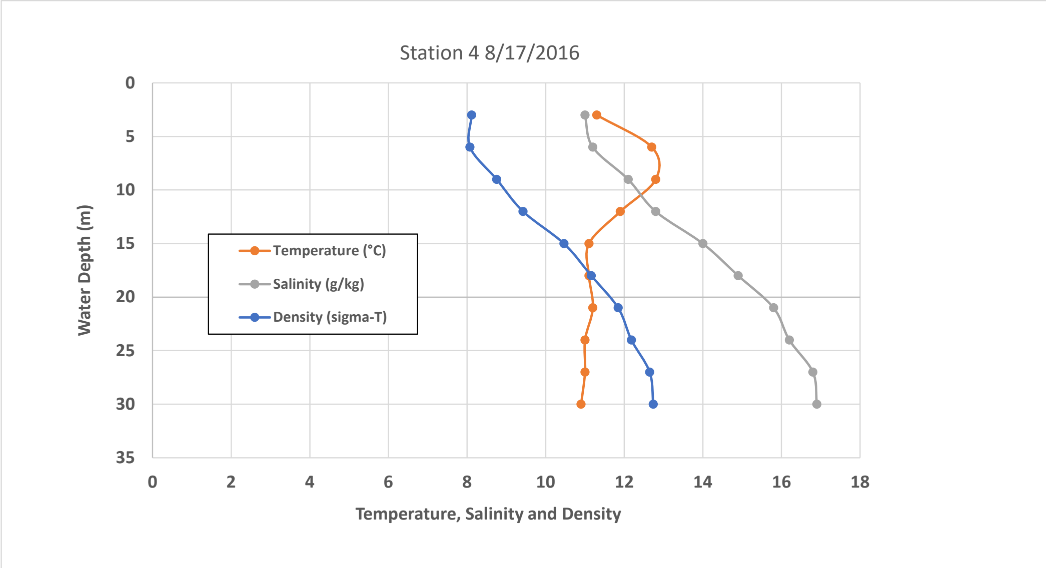

Figure 27. Vertical Ambient Profile of Temperature, Salinity and Density in Wrangell Mixing Zone Resulting in Least Mixing

Mixing zone dilution modeling results for Wrangell are summarized in Table 8. Two of the applicable initial mixing models, UM and DKHW, gave different results for dilution at a distance of 1*depth (30.5 m; simulations 3 vs. 4). The third initial mixing model, NRFIELD, predicted a lower DF at a distance shorter than 1*depth (16.8 m; simulations 5 vs. 6). UM3 gave more conservative DF results (simulation 7) when run using the downstream-only cross-diffuser merging, so we selected this approach for further analysis at Wrangell. The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Sensitivity of the far-field model to bounding values of the diffusion parameter α was found to have a significant effect on dilution factors, as was substituting the 4/3-power law with linear eddy diffusivity.

Dilution factors at distances of 1*depth to 10*depth range from 112 to 229 (Table 8, simulations 10-13); accounting for bacterial decay had a negligible effect on dilution factors. Graphical examples of the dilution model predictions are presented in Figures 28 (plan view from above of the discharge plume boundary), 29 (profile view from the side of the discharge plume centerline and boundary) and 30 (discharge plume average and centerline dilution vs. distance from the outfall). As shown in Table 8, the plume was trapped at a depth of 24 m by the ambient density stratification, the initial mixing region extended 12 m from the outfall, and the travel time to the mixing zone boundaries ranged from 8 minutes (MZ=1*depth) to 122 minutes (MZ=10*depth). A dilution factor of 112 was predicted for the boundary of the initial mixing region and at the distance to the shore (457 m) the DF was 323.

The initial mixing model was moderately sensitive to a number of inputs (effluent temperature, current velocity and direction, and discharge flow rate) is demonstrated in simulations 16-24 (Table 8). DFs were sensitive to variation in ambient velocity (dilution increasing with velocity, simulations 17-19) and effluent flow rate (dilution decreases with Q, simulations 21-24).

Table 8. Wrangell Mixing Zone Dilution Modeling Results

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[19]
1. MZ=1*depth	Wrangell station 4 8/2015	UM3(half spacing)/FF	30.5	34	262	274	23	15	7
2. " "	Wrangell station 3 8/2016	" "	" "	33	232	243	23	13	8
3. " "	Wrangell station 4 8/2016	" "	" "	32	153	160	25	10	8
4. " "	" "	DKHW(half spacing)/FF	" "	32	228	228	26	11	8
5. " "	" "	UM3 (half spacing)/FF	16.8	32	153	157	25	10	3
6. " "	" "	NRFIELD	16.8	33	75		25		
7. " "	" "	UM3(DS-only, 8x3.95")/FF	30.5	33	112	117	24	12	8
8. " "	Wrangell station 3 8/2017	UM3(half-spacing)/FF	" "	39	494	516	17	25	2
9. " "	Wrangell station 4 8/2017	" "	" "	40	743	791	6	21	4
Dilution at different distances:									
10. MZ= initial mixing region	Wrangell station 4 8/2016	UM3 (DS-only, 8x3.95")	12	33	**112**	113	24		2
11. MZ=1*depth	" "	UM3(DS-only, 8x3.95")/FF	30.5	33	**112**	113	24	12	8
12. MZ=2*depth	" "	" "	61	33	**115**	115	24	12	20
13. MZ=5*depth	" "	" "	152.5	33	**149**	149	24	12	59
14. MZ=10*depth	" "	" "	305	33	**229**	230	24	12	122

[19] Travel time to MZ boundary was calculated only for distances exceeding length of initial mixing region.

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[19]
15. MZ=distance to nearest shore	" "	" "	457	33	**323**	325	24	12	185
Model sensitivity:									
16. avg. effluent T=17.3° C	Wrangell station 4 8/2016	UM3(DS-only, 8x3.95")/FF	30.5	33	112	112	24	12	8
17. ½*current v=2 cm/s	" "	" "	" "	33	86	86	24	11	16
18. 2*current v=8 cm/s	" "	" "	" "	33	198	199	25	15	3
19. ave. current v=23.5 cm/s	" "	UM3 (DS-only, 8x3.95")	" "	33	412	412	27	31	2
20. reverse current direction=270°	" "	UM3(DS-only, 8x3.95")/FF	" "	33	112	113	24	12	8
21. ave. Q=0.36 MGD	" "	" "	" "	3.9	243	244	26	5	11
22. Q/4=0.75 MGD	" "	" "	" "	8.1	161	161	25	6	10
23. Q/2=1.5 MGD	" "	" "	" "	16	125	126	25	8	9
24. 2*Q=6.0 MGD	" "	" "	" "	65	119	120	25	18	5
Far-field model sensitivity to diffusion parameter:									
25. alpha=0.0001	Wrangell station 4 8/2016	UM3(DS-only, 8x3.95")/FF	305	33	130	131	24	12	122
26. alpha=0.000453	" "	" "	" "	33	321	323	24	12	122
27. Linear eddy diffusivity	" "	" "	" "	33	203	204	24	12	122

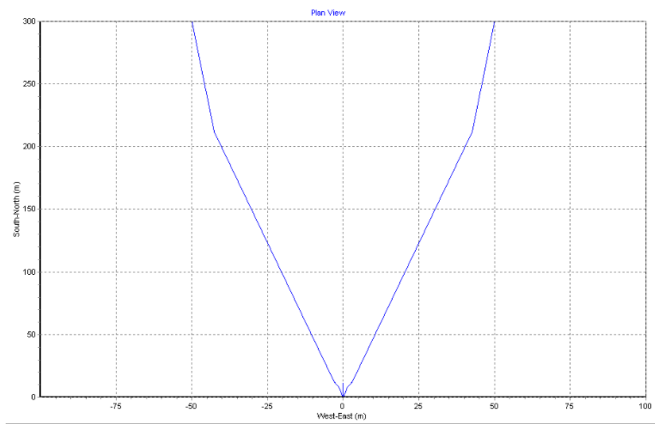

Figure 28. Wrangell Discharge Plume Boundary Plan View from Above

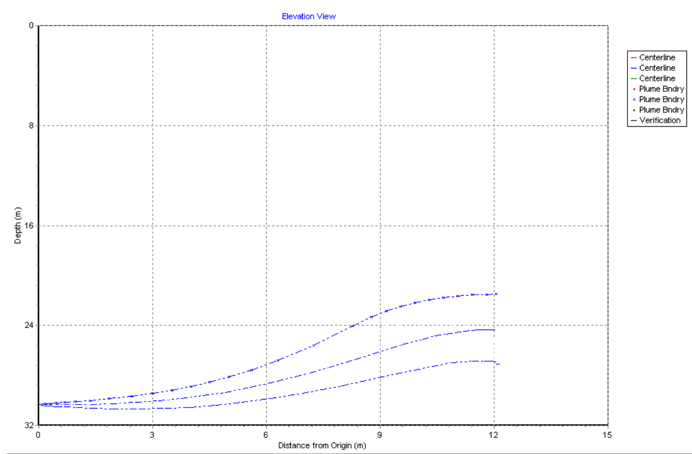

Figure 29. Wrangell Discharge Plume Centerline and Boundary Profile View from Side

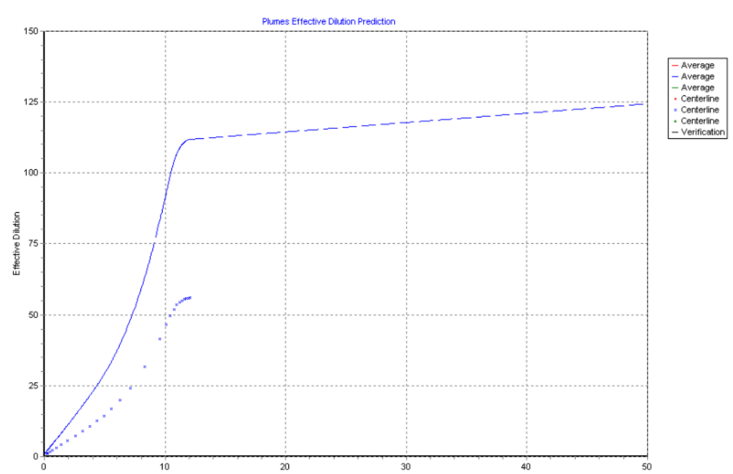

Figure 30. Wrangell Discharge Plume Average and Centerline Dilution vs. Distance from Outfall

SUMMARY

A summary of the average dilution predictions at various distances (corresponding to 1-10 times the depth of discharge) from the discharge point at each Alaskan mixing zone location is presented in Table 9. As indicated in this table, some of the distances exceed the distance from the outfall to the nearest shore. Under some conditions the tidal currents could direct the discharge plume towards the shore and, upon reaching this boundary, further mixing would likely not occur. The distance from the outfall to nearest shore at each location and the predicted DFs and travel times for these distances are presented in Table 10. The dilution predictions are also graphed as a function of distance from the outfall (Figure 31). In this figure, DFs for Ketchikan, Sitka and Skagway have been truncated at the distance to shore.

Table 9. Average Dilution Factor Predictions at Distances from the Discharge Point Corresponding to 1-10 Times the Depth of Discharge

Location	1*depth			2*depth			5*depth			10*depth		
	Distance (m)	DF	Time (min)	Distance (m)	DF	Time (min)	Distance (m)	DF	Time (min)	Distance (m)	DF	Time (min)
Haines	21.3	100	4	43	136	19	107	330	65	213	766	143
Ketchikan	29.9	52	5	60	62	13	150	105	39	299*	179	81
Petersburg	18.3	67	1	37	90	15	92	256	72	183	647	167
Sitka	24.4	87	17	49	97	41	122*	143	113	244*	227	232
Skagway	18.3	56	18	37	86	39	92	177	105	183*	330	214
Wrangell	30.5	112	8	61	115	20	153	149	59	305	229	122

* Distance greater than the distance from the outfall to shore.

Table 10. Average Dilution Factor Predictions at the Distance from the Outfall to Shore

Location	Distance from outfall to shore (m)	DF at distance from outfall to shore	Travel time to shore (min)
Haines	549	2770	386
Ketchikan	221	141	59
Petersburg	366	1720	358
Sitka	114	138	105
Skagway	125	233	145
Wrangell	457	323	185

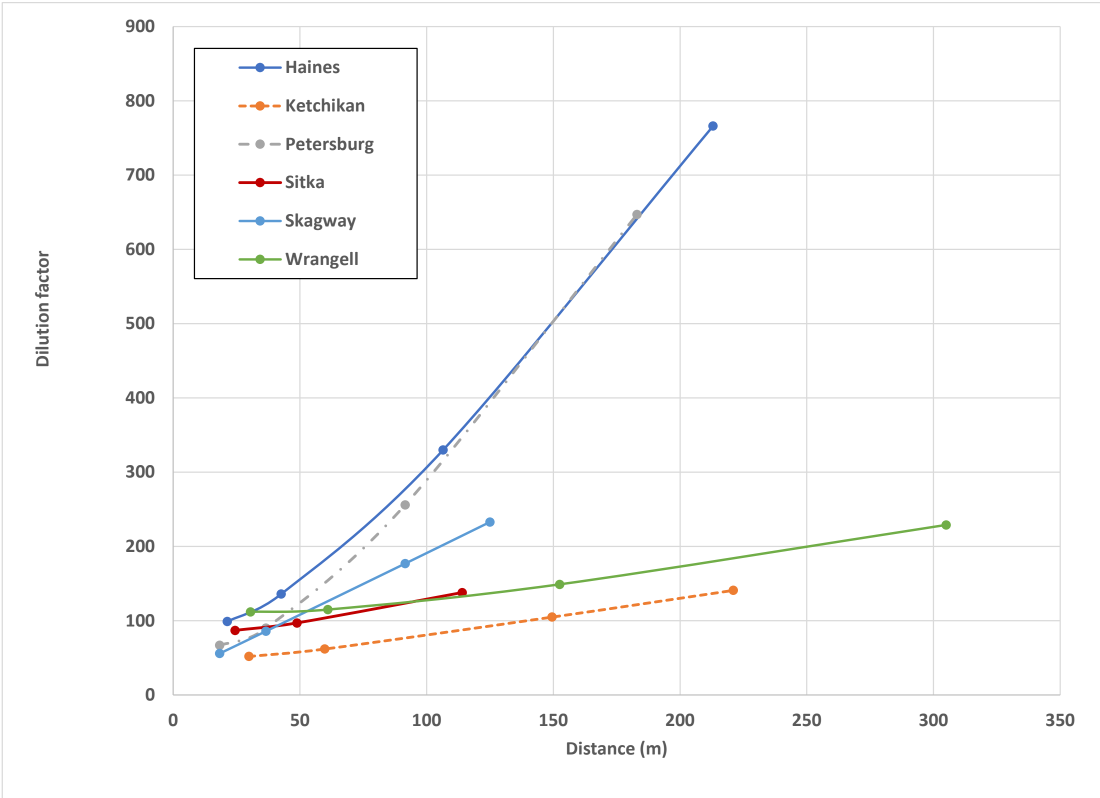

Figure 31. DF Predictions Graphed as a Function of Distance from the Outfall
(predictions are DFs for distances corresponding to 1-10 times the depth of discharge; in the cases of Ketchikan, Sitka and Skagway, DFs have been truncated at the distances to the shore)

A summary of the dilution factors predicted at the initial mixing region boundaries is presented in Table 11. For each location this table includes the distance to this boundary, the predicted DF and the travel times to the boundary. Compared to the depth-based distances in Table 9, the initial mixing region boundary distances are quite short, although the DFs at a distance of 1*depth are comparable (within 25%) of the initial mixing region dilution factors.

Table 11. Dilution Factor Predictions at Distances Equal to Initial Mixing Region Boundaries

Location	Initial Mixing Region Boundary (m)	DF	Travel Time to Boundary (min)
Haines	16	99	1
Ketchikan	13	51	1
Petersburg	23	74	1
Sitka	6.9	86	1
Skagway	3.5	42	0.7
Wrangell	12	112	2

The far-field model was also used to calculate the distances required to attain the FC criteria (i.e., the DFs in Table 1). These distances, presented in Table 11, range from 3.4 to 135 km to attain the 43/100 mL FC criterion and 7.2 to 420 km to attain the 14/100 mL FC criterion. These distances greatly exceed the mixing zone sizes certified by the state in the current wastewater discharge permits for the six POTW facilities.

Table 12. Dilution Factors and Mixing Zone Distances Required to Attain FC Criteria

Location	DF required to attain the 43/100 mL FC criterion	Distance to attain the 43/100 mL FC criterion (km)	DF required to attain the 14/100 mL FC criterion	Distance to attain the 14/100 mL FC criterion (km)
Haines	50,000	4.0	150,000	8.3
Ketchikan	67,000	135	210,000	420
Petersburg	47,000	3.4	140,000	7.2
Sitka	87,000	126	270,000	390
Skagway	60,000	36	190,000	114
Wrangell	4,400	3.9	14,000	8.9

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APPENDIX: VP AND FARFIELD[20] OUTPUT FOR EACH LOCATION

Haines (model output for 1*depth, 2*depth, 5*depth and 10*depth)

Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Haines" memo4

Model configuration items checked: Brooks far-field solution;
Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
Bacteria model : Mancini (1978) coliform model
PDS sfc. model heat transfer : Medium
Equation of State : S, T
Similarity Profile : Default profile (k=2.0, ...)
Diffuser port contraction coefficient 0.61
Light absorption coefficient 0.16
Farfield increment (m) 200
UM3 aspiration coefficient 0.1
Output file: text output tab
Output each ?? steps 100
Maximum dilution reported 100000
Text output format : Standard
Max vertical reversals : to max rise or fall

/ UM3. 6/23/2021 5:19:37 AM
Case 1; ambient file C:\Plumes20\Haines_Skagway_1_Jun05.006.db; Diffuser table record 1: --------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.023	90.00	7.100	11.12	0.0	0.000192	0.023	90.00	0.0003	5.180276
1.523	0.023	90.00	14.16	10.08	0.0	0.000194	0.023	90.00	0.0003	10.78304
3.047	0.023	90.00	23.30	8.650	0.0	0.000193	0.023	90.00	0.0003	18.06627
4.570	0.023	90.00	23.25	8.670	0.0	0.000193	0.023	90.00	0.0003	18.02474
6.090	0.023	90.00	25.20	8.220	0.0	0.000193	0.023	90.00	0.0003	19.60292
7.617	0.023	90.00	26.37	8.020	0.0	0.000193	0.023	90.00	0.0003	20.54204
9.140	0.023	90.00	26.74	7.980	0.0	0.000193	0.023	90.00	0.0003	20.83621
10.45	0.023	90.00	27.46	7.570	0.0	0.000193	0.023	90.00	0.0003	21.45192
11.75	0.023	90.00	28.24	7.100	0.0	0.000193	0.023	90.00	0.0003	22.12180
13.06	0.023	90.00	28.92	6.920	0.0	0.000193	0.023	90.00	0.0003	22.67724
14.37	0.023	90.00	29.08	6.880	0.0	0.000192	0.023	90.00	0.0003	22.80770
15.68	0.023	90.00	29.29	6.790	0.0	0.000192	0.023	90.00	0.0003	22.98359
16.98	0.023	90.00	30.42	6.260	0.0	0.000192	0.023	90.00	0.0003	23.93584

[20] If required.

22.00 0.023 90.00 34.78 4.213 0.0 0.000192 0.023 90.00 0.0003 27.61629

Diffuser table:
P-diaVer angl H-Angle SourceX SourceY Ports Spacing MZ-dis Isoplth P-depth Ttl-flo Eff-sal Temp Polutnt
(in) (deg) (deg) (m) (m) () (ft) (m)(concent) (m) (MGD) (psu) (C)(col/dl)
3.0000 0.0 90.000 0.0 0.0 2.0000 15.000 21.300 200.00 21.100 2.9000 0.0 15.800 2.13E+6

Simulation:
Froude No: 178.8; Strat No: 2.20E-3; Spcg No: 76.82; k: 992.9; eff den (sigmaT) -0.960860; eff vel 22.84(m/s);

Step	Depth (m)	Amb-cur (cm/s)	P-dia (in)	Polutnt (col/dl)	Dilutn ()	x-posn (m)	y-posn (m)	Iso dia (m)
0	21.10	2.300	2.343	2.130E+6	1.000	0.0	0.0	0.0; 10.68 T-90hr,
100	21.10	2.300	23.86	208749.0	10.20	0.000	1.346	0.6058; 10.68 T-90hr,
160	21.03	2.300	77.28	63725.7	33.42	0.000	4.775	1.9614; bottom hit; 10.65 T-90hr,
200	20.49	2.300	166.7	28847.1	73.76	0.000	10.62	4.2261; 10.42 T-90hr,
204	20.37	2.300	179.9	26645.8	79.84	0.000	11.48	4.5599; trap level; 10.37 T-90hr,
205	20.34	2.300	183.3	26122.1	81.44	0.000	11.71	4.6475; merging; 10.36 T-90hr,
232	19.97	2.300	305.7	21392.8	99.34	0.000	16.27	7.7425; local maximum rise or fall; 10.20 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 16.274
Lmz(m): 16.274
forced entrain 1 1.873 1.132 7.764 1.000
Rate sec-1 0.00019515 dy-1 16.8607 kt: 0.000062421 Amb Sal 33.0175
Const Eddy Diffusivity. Farfield dispersion based on wastefield width of 12.34 m

conc (col/dl)	dilutn	width (m)	distnce (m)	time (hrs)	bckgrnd (col/dl)	decay (ly/hr)	current (cm/s)	cur-dir angle	eddydif (m0.67/s2)
21392.8	99.34	12.34	16.27	2.78E-4	0.0	16.27	2.300	90.00	3.00E-4 6.2421E-5
20539.8	99.48	14.21	21.30	0.061	0.0	16.27	2.300	90.00	3.00E-4 6.2421E-5
18354.2	113.1	20.80	37.57	0.258	0.0	16.27	2.300	90.00	3.00E-4 6.2421E-5

count: 1
;
5:19:40 AM. amb fills: 4
/ UM3. 6/23/2021 5:20:06 AM
Case 1; ambient file C:\Plumes20\Haines_Skagway_1_Jun05.006.db; Diffuser table record 1: ----------------------------------

Ambient Table:

Depth m	Amb-cur m/s	Amb-dir deg	Amb-sal psu	Amb-tem C	Amb-pol kg/kg	Solar rad s-1	Far-spd m/s	Far-dir deg	Disprsn m0.67/s2	Density sigma-T
0.0	0.023	90.00	7.100	11.12	0.0	0.000194	0.023	90.00	0.0003	5.180276
1.523	0.023	90.00	14.16	10.08	0.0	0.000198	0.023	90.00	0.0003	10.78304
3.047	0.023	90.00	23.30	8.650	0.0	0.000197	0.023	90.00	0.0003	18.06627
4.570	0.023	90.00	23.25	8.670	0.0	0.000196	0.023	90.00	0.0003	18.02474
6.090	0.023	90.00	25.20	8.220	0.0	0.000196	0.023	90.00	0.0003	19.60292
7.617	0.023	90.00	26.37	8.020	0.0	0.000196	0.023	90.00	0.0003	20.54204
9.140	0.023	90.00	26.74	7.980	0.0	0.000196	0.023	90.00	0.0003	20.83621
10.45	0.023	90.00	27.46	7.570	0.0	0.000196	0.023	90.00	0.0003	21.45192

11.75	0.023	90.00	28.24	7.100	0.0	0.000196	0.023	90.00	0.0003	22.12180
13.06	0.023	90.00	28.92	6.920	0.0	0.000195	0.023	90.00	0.0003	22.67724
14.37	0.023	90.00	29.08	6.880	0.0	0.000195	0.023	90.00	0.0003	22.80770
15.68	0.023	90.00	29.29	6.790	0.0	0.000195	0.023	90.00	0.0003	22.98359
16.98	0.023	90.00	30.42	6.260	0.0	0.000195	0.023	90.00	0.0003	23.93584
22.00	0.023	90.00	34.78	4.213	0.0	0.000195	0.023	90.00	0.0003	27.61629

Diffuser table:
P-diaVer angl H-Angle SourceX SourceY Ports Spacing MZ-dis Isoplth P-depth Ttl-flo Eff-sal Temp Polutnt
(in) (deg) (deg) (m) (m) () (ft) (m)(concent) (m) (MGD) (psu) (C)(col/dl)
3.0000 0.0 90.000 0.0 0.0 2.0000 15.000 42.600 200.00 21.100 2.9000 0.0 15.800 2.13E+6

Simulation:
Froude No: 178.8; Strat No: 2.20E-3; Spcg No: 76.82; k: 992.9; eff den (sigmaT) -0.960860; eff vel 22.84(m/s);
Depth Amb-cur P-dia Polutnt Dilutn x-posn y-posn Iso dia
Step (m) (cm/s) (in) (col/dl) () (m) (m) (m)
0 21.10 2.300 2.343 2.130E+6 1.000 0.0 0.0 0.05935; 10.68 T-90hr,
100 21.10 2.300 23.86 208749.0 10.20 0.000 1.346 0.6058; 10.68 T-90hr,
160 21.03 2.300 77.28 63725.7 33.42 0.000 4.775 1.9614; bottom hit; 10.65 T-90hr,
200 20.49 2.300 166.7 28847.1 73.76 0.000 10.62 4.2261; 10.42 T-90hr,
204 20.37 2.300 179.9 26645.8 79.84 0.000 11.48 4.5599; trap level; 10.37 T-90hr,
205 20.34 2.300 183.3 26122.1 81.44 0.000 11.71 4.6475; merging; 10.36 T-90hr,
232 19.97 2.300 305.7 21392.8 99.34 0.000 16.27 7.7425; local maximum rise or fall; 10.20 T-90hr,
Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 16.274
Lmz(m): 16.274
forced entrain 1 1.873 1.132 7.764 1.000
Rate sec-1 0.00019515 dy-1 16.8607 kt: 0.000062421 Amb Sal 33.0175
Const Eddy Diffusivity. Farfield dispersion based on wastefield width of 12.34 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
21392.8 99.34 12.34 16.27 2.78E-4 0.0 16.27 2.300 90.00 3.00E-4 6.2421E-5
19386.1 118.7 23.00 42.60 0.318 0.0 16.27 2.300 90.00 3.00E-4 6.2421E-5
15243.7 136.7 30.62 58.87 0.515 0.0 16.27 2.300 90.00 3.00E-4 6.2421E-5
count: 1
;
5:20:07 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
	4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	99.34	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	12.34	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	16.27	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	42.6	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.023	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	2.14E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 8.5548E-03 m^2/s
Beta = 3.6170E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	0.317995169	26.33	42.6	1.36E+02	1.56E+04	137

/ UM3. 6/23/2021 5:20:24 AM
Case 1; ambient file C:\Plumes20\Haines_Skagway_1_Jun05.006.db; Diffuser table record 1: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.023	90.00	7.100	11.12	0.0	0.000194	0.023	90.00	0.0003	5.180276
1.523	0.023	90.00	14.16	10.08	0.0	0.000198	0.023	90.00	0.0003	10.78304
3.047	0.023	90.00	23.30	8.650	0.0	0.000197	0.023	90.00	0.0003	18.06627
4.570	0.023	90.00	23.25	8.670	0.0	0.000196	0.023	90.00	0.0003	18.02474
6.090	0.023	90.00	25.20	8.220	0.0	0.000196	0.023	90.00	0.0003	19.60292
7.617	0.023	90.00	26.37	8.020	0.0	0.000196	0.023	90.00	0.0003	20.54204
9.140	0.023	90.00	26.74	7.980	0.0	0.000196	0.023	90.00	0.0003	20.83621
10.45	0.023	90.00	27.46	7.570	0.0	0.000196	0.023	90.00	0.0003	21.45192
11.75	0.023	90.00	28.24	7.100	0.0	0.000196	0.023	90.00	0.0003	22.12180
13.06	0.023	90.00	28.92	6.920	0.0	0.000195	0.023	90.00	0.0003	22.67724
14.37	0.023	90.00	29.08	6.880	0.0	0.000195	0.023	90.00	0.0003	22.80770
15.68	0.023	90.00	29.29	6.790	0.0	0.000195	0.023	90.00	0.0003	22.98359
16.98	0.023	90.00	30.42	6.260	0.0	0.000195	0.023	90.00	0.0003	23.93584
22.00	0.023	90.00	34.78	4.213	0.0	0.000195	0.023	90.00	0.0003	27.61629

Diffuser table:

P-dia	Ver angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.0000	0.0	90.000	0.0	0.0	2.0000	15.000	106.50	200.00	21.100	2.9000	0.0	15.800	2.13E+6

Simulation:
Froude No: 178.8; Strat No: 2.20E-3; Spcg No: 76.82; k: 992.9; eff den (sigmaT) -0.960860; eff vel 22.84(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Iso dia	
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(m)	
0	21.10	2.300	2.343	2.130E+6	1.000	0.0	0.0	0.05935;	10.68 T-90hr,
100	21.10	2.300	23.86	208749.0	10.20	0.000	1.346	0.6058;	10.68 T-90hr,
160	21.03	2.300	77.28	63725.7	33.42	0.000	4.775	1.9614;	bottom hit; 10.65 T-90hr,
200	20.49	2.300	166.7	28847.1	73.76	0.000	10.62	4.2261;	10.42 T-90hr,
204	20.37	2.300	179.9	26645.8	79.84	0.000	11.48	4.5599;	trap level; 10.37 T-90hr,
205	20.34	2.300	183.3	26122.1	81.44	0.000	11.71	4.6475;	merging; 10.36 T-90hr,
232	19.97	2.300	305.7	21392.8	99.34	0.000	16.27	7.7425;	local maximum rise or fall; 10.20 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 16.274
Lmz(m): 16.274
forced entrain 1 1.873 1.132 7.764 1.000
Rate sec-1 0.00019515 dy-1 16.8607 kt: 0.000062421 Amb Sal 33.0175
Const Eddy Diffusivity. Farfield dispersion based on wastefield width of 12.34 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)

```
 21392.8   99.34   12.34   16.27 2.78E-4    0.0   16.27   2.300   90.00 3.00E-4 6.2421E-5
 16299.5   181.1   56.68   106.5   1.090    0.0   16.27   2.300   90.00 3.00E-4 6.2421E-5
 10795.8   194.1   66.75   122.8   1.287    0.0   16.27   2.300   90.00 3.00E-4 6.2421E-5
count: 1
 ;
5:20:24 AM. amb fills: 4
```

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
	4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	99.34	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	12.34	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	16.27	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	106.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.023	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	2.14E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

			Eo =	8.5548E-03	m^2/s	
			Beta =	3.6170E-01	unitless	
	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	1.0897343	90.23	106.5	3.30E+02	6.43E+03	331

/ UM3. 6/23/2021 5:20:41 AM
Case 1; ambient file C:\Plumes20\Haines_Skagway_1_Jun05.006.db; Diffuser table record 1: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.023	90.00	7.100	11.12	0.0	0.000194	0.023	90.00	0.0003	5.180276
1.523	0.023	90.00	14.16	10.08	0.0	0.000198	0.023	90.00	0.0003	10.78304
3.047	0.023	90.00	23.30	8.650	0.0	0.000197	0.023	90.00	0.0003	18.06627
4.570	0.023	90.00	23.25	8.670	0.0	0.000196	0.023	90.00	0.0003	18.02474
6.090	0.023	90.00	25.20	8.220	0.0	0.000196	0.023	90.00	0.0003	19.60292
7.617	0.023	90.00	26.37	8.020	0.0	0.000196	0.023	90.00	0.0003	20.54204
9.140	0.023	90.00	26.74	7.980	0.0	0.000196	0.023	90.00	0.0003	20.83621
10.45	0.023	90.00	27.46	7.570	0.0	0.000196	0.023	90.00	0.0003	21.45192
11.75	0.023	90.00	28.24	7.100	0.0	0.000196	0.023	90.00	0.0003	22.12180
13.06	0.023	90.00	28.92	6.920	0.0	0.000195	0.023	90.00	0.0003	22.67724
14.37	0.023	90.00	29.08	6.880	0.0	0.000195	0.023	90.00	0.0003	22.80770
15.68	0.023	90.00	29.29	6.790	0.0	0.000195	0.023	90.00	0.0003	22.98359
16.98	0.023	90.00	30.42	6.260	0.0	0.000195	0.023	90.00	0.0003	23.93584
22.00	0.023	90.00	34.78	4.213	0.0	0.000195	0.023	90.00	0.0003	27.61629

Diffuser table:

P-dia	Ver angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.0000	0.0	90.000	0.0	0.0	2.0000	15.000	213.00	200.00	21.100	2.9000	0.0	15.800	2.13E+6

Simulation:
Froude No: 178.8; Strat No: 2.20E-3; Spcg No: 76.82; k: 992.9; eff den (sigmaT) -0.960860; eff vel 22.84(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Iso dia	
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(m)	
0	21.10	2.300	2.343	2.130E+6	1.000	0.0	0.0	0.05935;	10.68 T-90hr,
100	21.10	2.300	23.86	208749.0	10.20	0.000	1.346	0.6058;	10.68 T-90hr,
160	21.03	2.300	77.28	63725.7	33.42	0.000	4.775	1.9614;	bottom hit; 10.65 T-90hr,
200	20.49	2.300	166.7	28847.1	73.76	0.000	10.62	4.2261;	10.42 T-90hr,
204	20.37	2.300	179.9	26645.8	79.84	0.000	11.48	4.5599;	trap level; 10.37 T-90hr,
205	20.34	2.300	183.3	26122.1	81.44	0.000	11.71	4.6475;	merging; 10.36 T-90hr,
232	19.97	2.300	305.7	21392.8	99.34	0.000	16.27	7.7425;	local maximum rise or fall; 10.20 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 16.274
Lmz(m): 16.274
forced entrain 1 1.873 1.132 7.764 1.000
Rate sec-1 0.00019515 dy-1 16.8607 kt: 0.000062421 Amb Sal 33.0175
Const Eddy Diffusivity. Farfield dispersion based on wastefield width of 12.34 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
21392.8 99.34 12.34 16.27 2.78E-4 0.0 16.27 2.300 90.00 3.00E-4 6.2421E-5

12646.5 246.9 121.4 200.0 2.219 0.0 16.27 2.300 90.00 3.00E-4 6.2421E-5
8191.65 256.7 134.2 216.3 2.416 0.0 16.27 2.300 90.00 3.00E-4 6.2421E-5
count: 1
;
5:20:41 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
	4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	99.34	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	12.34	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	16.27	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	213	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.023	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	2.14E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT						
			Eo =	8.5548E-03	m^2/s	
			Beta =	3.6170E-01	unitless	
	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	2.375966184	196.73	213	7.66E+02	2.77E+03	768

Ketchikan (model output for 1*depth, 2*depth, 5*depth and 10*depth)

Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Ketchikan_1port" memo

Model configuration items checked: Brooks far-field solution;
Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
Bacteria model : Mancini (1978) coliform model
PDS sfc. model heat transfer : Medium
Equation of State : S, T
Similarity Profile : Default profile (k=2.0, ...)
Diffuser port contraction coefficient 0.61
Light absorption coefficient 0.16
Farfield increment (m) 200
UM3 aspiration coefficient 0.1
Output file: text output tab
Output each ?? steps 100
Maximum dilution reported 100000
Text output format : Standard
Max vertical reversals : to max rise or fall

/ UM3. 6/23/2021 5:27:49 AM
Case 1; ambient file C:\Plumes20\Ketchikan_3_July1997.004.db; Diffuser table record 3: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.059	140.0	24.50	15.20	0.0	0.000196	0.059	140.0	0.0003	17.89918
1.000	0.059	140.0	24.50	15.20	0.0	0.0002	0.059	140.0	0.0003	17.89918
16.10	0.059	140.0	26.80	13.80	0.0	0.0002	0.059	140.0	0.0003	19.93814
33.90	0.059	140.0	30.90	8.000	0.0	0.000199	0.059	140.0	0.0003	24.08526

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
12.000	0.0	205.00	0.0	0.0	1.0000	29.900	100.00	29.600	3.4560	0.0	20.500	20000.0

Simulation:
Froude No: 14.08; Strat No: 1.68E-3; Spcg No: 9.00E+8; k: 57.66; eff den (sigmaT) -1.837438; eff vel 3.402(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)	
0	29.60	5.900	9.372	20000.0	1.000	0.0	0.0	0.0	0.2374;	13.41 T-90hr,
100	29.37	5.900	61.18	2975.1	6.722	-2.606	-1.081	3.096	1.5410;	13.32 T-90hr,

200 27.61 5.900 135.6 1142.4 17.50 -6.017 -2.060 14.40 3.3681; 12.62 T-90hr,
249 24.16 5.900 233.0 562.5 35.49 -9.308 -2.435 34.83 5.6507; trap level; 11.26 T-90hr,
276 22.92 5.900 300.9 445.7 44.77 -10.56 -2.414 45.33 7.2032; begin overlap; 10.77 T-90hr,
300 22.48 5.900 333.7 414.4 48.13 -11.13 -2.377 50.59 7.9496; 10.60 T-90hr,
400 21.94 5.900 383.7 388.9 51.25 -12.54 -2.254 64.07 9.1014; 10.40 T-90hr,
417 21.94 5.900 385.5 387.6 51.42 -12.73 -2.235 65.91 9.1403; local maximum rise or fall; 10.39 T-90hr,
Horiz plane projections in effluent direction: radius(m): 2.4839; CL(m): 12.480
Lmz(m): 14.964
forced entrain 1 1.28E+9 7.663 9.791 1.000
Rate sec-1 0.00019971 dy-1 17.2550 kt: 0.000059972 Amb Sal 28.1446
4/3 Power Law. Farfield dispersion based on wastefield width of 9.79 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
387.592 51.42 9.799 12.92 2.78E-4 0.0 16.00 5.900 140.0 3.00E-4 5.9972E-5
372.140 52.31 12.10 29.90 0.0802 0.0 16.00 5.900 140.0 3.00E-4 5.9972E-5
346.023 56.38 13.95 42.82 0.141 0.0 16.00 5.900 140.0 3.00E-4 5.9972E-5
count: 1
;
5:27:49 AM. amb fills: 4

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	51.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	9.79	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.92	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	29.9	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.42E-04	
4. Horizontal current speed (m/sec)	0.059	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	3.88E+02	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	2.00E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

			Eo =	6.2830E-03	m^2/s	
			Beta =	1.3053E-01	unitless	
	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	7.99E-02	16.98	29.90	5.22E+01	3.82E+02	52

/ UM3. 6/23/2021 5:28:05 AM
Case 1; ambient file C:\Plumes20\Ketchikan_3_July1997.004.db; Diffuser table record 3: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.059	140.0	24.50	15.20	0.0	0.000195	0.059	140.0	0.0003	17.89918
1.000	0.059	140.0	24.50	15.20	0.0	0.0002	0.059	140.0	0.0003	17.89918
16.10	0.059	140.0	26.80	13.80	0.0	0.0002	0.059	140.0	0.0003	19.93814
33.90	0.059	140.0	30.90	8.000	0.0	0.000199	0.059	140.0	0.0003	24.08526

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
12.000	0.0	205.00	0.0	0.0	1.0000	59.800	100.00	29.600	3.4560	0.0	20.500	20000.0

Simulation:
Froude No: 14.08; Strat No: 1.68E-3; Spcg No: 9.00E+8; k: 57.66; eff den (sigmaT) -1.837438; eff vel 3.402(m/s);

Step	Depth (m)	Amb-cur (cm/s)	P-dia (in)	Polutnt (col/dl)	Dilutn ()	x-posn (m)	y-posn (m)	Time (s)	Iso dia (m)
0	29.60	5.900	9.372	20000.0	1.000	0.0	0.0	0.0	0.2222; 13.41 T-90hr,
100	29.37	5.900	61.18	2975.1	6.722	-2.606	-1.081	3.096	1.5410; 13.32 T-90hr,
200	27.61	5.900	135.6	1142.4	17.50	-6.017	-2.060	14.40	3.3681; 12.62 T-90hr,
249	24.16	5.900	233.0	562.5	35.49	-9.308	-2.435	34.83	5.6507; trap level; 11.26 T-90hr,
276	22.92	5.900	300.9	445.7	44.77	-10.56	-2.414	45.33	7.2032; begin overlap; 10.77 T-90hr,
300	22.48	5.900	333.7	414.4	48.13	-11.13	-2.377	50.59	7.9496; 10.60 T-90hr,
400	21.94	5.900	383.7	388.9	51.25	-12.54	-2.254	64.07	9.1014; 10.40 T-90hr,
417	21.94	5.900	385.5	387.6	51.42	-12.73	-2.235	65.91	9.1403; local maximum rise or fall; 10.39 T-90hr,

Horiz plane projections in effluent direction: radius(m): 2.4839; CL(m): 12.480
Lmz(m): 14.964
forced entrain 1 1.28E+9 7.663 9.791 1.000
Rate sec-1 0.00019971 dy-1 17.2550 kt: 0.000059972 Amb Sal 28.1446
4/3 Power Law. Farfield dispersion based on wastefield width of 9.79 m

conc (col/dl)	dilutn	width (m)	distnce (m)	time (hrs)	bckgrnd (col/dl)	decay (ly/hr)	current (cm/s)	cur-dir angle	eddydif (m0.67/s2)	
387.592	51.42	9.799	12.92	2.78E-4	0.0	16.00	5.900	140.0	3.00E-4	5.9972E-5
361.000	64.47	16.52	59.80	0.221	0.0	16.00	5.900	140.0	3.00E-4	5.9972E-5
273.501	71.65	18.57	72.72	0.282	0.0	16.00	5.900	140.0	3.00E-4	5.9972E-5

count: 1
;

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	51.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	9.79	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.92	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	59.8	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.42E-04	
4. Horizontal current speed (m/sec)	0.059	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	3.88E+02	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	2.00E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.2830E-03 m^2/s
Beta = 1.3053E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	2.21E-01	46.88	59.80	6.24E+01	3.19E+02	63

5:28:05 AM. amb fills: 4
/ UM3. 6/23/2021 5:28:34 AM
Case 1; ambient file C:\Plumes20\Ketchikan_3_July1997.004.db; Diffuser table record 3: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.059	140.0	24.50	15.20	0.0	0.000195	0.059	140.0	0.0003	17.89918
1.000	0.059	140.0	24.50	15.20	0.0	0.0002	0.059	140.0	0.0003	17.89918
16.10	0.059	140.0	26.80	13.80	0.0	0.0002	0.059	140.0	0.0003	19.93814
33.90	0.059	140.0	30.90	8.000	0.0	0.000199	0.059	140.0	0.0003	24.08526

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
12.000	0.0	205.00	0.0	0.0	1.0000	149.50	100.00	29.600	3.4560	0.0	20.500	20000.0

Simulation:
Froude No: 14.08; Strat No: 1.68E-3; Spcg No: 9.00E+8; k: 57.66; eff den (sigmaT) -1.837438; eff vel 3.402(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)
0	29.60	5.900	9.372	20000.0	1.000	0.0	0.0	0.0	0.2222; 13.41 T-90hr,
100	29.37	5.900	61.18	2975.1	6.722	-2.606	-1.081	3.096	1.5410; 13.32 T-90hr,
200	27.61	5.900	135.6	1142.4	17.50	-6.017	-2.060	14.40	3.3681; 12.62 T-90hr,
249	24.16	5.900	233.0	562.5	35.49	-9.308	-2.435	34.83	5.6507; trap level; 11.26 T-90hr,
276	22.92	5.900	300.9	445.7	44.77	-10.56	-2.414	45.33	7.2032; begin overlap; 10.77 T-90hr,
300	22.48	5.900	333.7	414.4	48.13	-11.13	-2.377	50.59	7.9496; 10.60 T-90hr,
400	21.94	5.900	383.7	388.9	51.25	-12.54	-2.254	64.07	9.1014; 10.40 T-90hr,
417	21.94	5.900	385.5	387.6	51.42	-12.73	-2.235	65.91	9.1403; local maximum rise or fall; 10.39 T-90hr,

Horiz plane projections in effluent direction: radius(m): 2.4839; CL(m): 12.480
Lmz(m): 14.964
forced entrain 1 1.28E+9 7.663 9.791 1.000
Rate sec-1 0.00019971 dy-1 17.2550 kt: 0.000059972 Amb Sal 28.1446
4/3 Power Law. Farfield dispersion based on wastefield width of 9.79 m

conc	dilutn	width	distnce	time	bckgrnd	decay	current	cur-dir	eddydif	
(col/dl)		(m)	(m)	(hrs)	(col/dl)	(ly/hr)	(cm/s)	angle	(m0.67/s2)	
387.592	51.42	9.799	12.92	2.78E-4	0.0	16.00	5.900	140.0	3.00E-4	5.9972E-5
329.541	122.8	32.26	149.5	0.643	0.0	16.00	5.900	140.0	3.00E-4	5.9972E-5
149.151	132.4	34.81	162.4	0.704	0.0	16.00	5.900	140.0	3.00E-4	5.9972E-5

count: 1
;
5:28:34 AM. amb fills: 4

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	51.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	9.79	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.92	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	149.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.42E-04	
4. Horizontal current speed (m/sec)	0.059	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	3.88E+02	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	2.00E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.2830E-03 m^2/s
Beta = 1.3053E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	6.43E-01	136.58	149.50	1.05E+02	1.89E+02	106

/ UM3. 6/23/2021 5:28:46 AM
Case 1; ambient file C:\Plumes20\Ketchikan_3_July1997.004.db; Diffuser table record 3: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.059	140.0	24.50	15.20	0.0	0.000195	0.059	140.0	0.0003	17.89918
1.000	0.059	140.0	24.50	15.20	0.0	0.0002	0.059	140.0	0.0003	17.89918
16.10	0.059	140.0	26.80	13.80	0.0	0.0002	0.059	140.0	0.0003	19.93814
33.90	0.059	140.0	30.90	8.000	0.0	0.000199	0.059	140.0	0.0003	24.08526

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
12.000	0.0	205.00	0.0	0.0	1.0000	299.00	100.00	29.600	3.4560	0.0	20.500	20000.0

Simulation:
Froude No: 14.08; Strat No: 1.68E-3; Spcg No: 9.00E+8; k: 57.66; eff den (sigmaT) -1.837438; eff vel 3.402(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)	
0	29.60	5.900	9.372	20000.0	1.000	0.0	0.0	0.0	0.2222;	13.41 T-90hr,
100	29.37	5.900	61.18	2975.1	6.722	-2.606	-1.081	3.096	1.5410;	13.32 T-90hr,
200	27.61	5.900	135.6	1142.4	17.50	-6.017	-2.060	14.40	3.3681;	12.62 T-90hr,
249	24.16	5.900	233.0	562.5	35.49	-9.308	-2.435	34.83	5.6507;	trap level; 11.26 T-90hr,
276	22.92	5.900	300.9	445.7	44.77	-10.56	-2.414	45.33	7.2032;	begin overlap; 10.77 T-90hr,
300	22.48	5.900	333.7	414.4	48.13	-11.13	-2.377	50.59	7.9496;	10.60 T-90hr,
400	21.94	5.900	383.7	388.9	51.25	-12.54	-2.254	64.07	9.1014;	10.40 T-90hr,
417	21.94	5.900	385.5	387.6	51.42	-12.73	-2.235	65.91	9.1403;	local maximum rise or fall; 10.39 T-90hr,

Horiz plane projections in effluent direction: radius(m): 2.4839; CL(m): 12.480
Lmz(m): 14.964
forced entrain 1 1.28E+9 7.663 9.791 1.000
Rate sec-1 0.00019971 dy-1 17.2550 kt: 0.000059972 Amb Sal 28.1446
4/3 Power Law. Farfield dispersion based on wastefield width of 9.79 m

conc	dilutn	width	distnce	time	bckgrnd	decay	current	cur-dir	eddydif	
(col/dl)		(m)	(m)	(hrs)	(col/dl)	(ly/hr)	(cm/s)	angle	(m0.67/s2)	
387.592	51.42	9.799	12.92	2.78E-4	0.0	16.00	5.900	140.0	3.00E-4	5.9972E-5
313.051	161.8	42.56	200.0	0.881	0.0	16.00	5.900	140.0	3.00E-4	5.9972E-5
94.9421	348.2	91.63	400.0	1.823	0.0	16.00	5.900	140.0	3.00E-4	5.9972E-5
54.9006	361.8	95.21	412.9	1.884	0.0	16.00	5.900	140.0	3.00E-4	5.9972E-5

count: 2
;

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	51.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	9.79	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.92	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	299	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.42E-04	
4. Horizontal current speed (m/sec)	0.059	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	3.88E+02	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	2.00E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

			Eo =	6.2830E-03	m^2/s	
			Beta =	1.3053E-01	unitless	
	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	1.35E+00	286.08	299.00	1.79E+02	1.11E+02	180

Petersburg (model output for 1*depth, 2*depth, 5*depth and 10*depth)

Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Petersburg" me

Model configuration items checked: Brooks far-field solution;
Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
Bacteria model : Mancini (1978) coliform model
PDS sfc. model heat transfer : Medium
Equation of State : S, T
Similarity Profile : Default profile (k=2.0, ...)
Diffuser port contraction coefficient 0.61
Light absorption coefficient 0.16
Farfield increment (m) 200
UM3 aspiration coefficient 0.1
Output file: text output tab
Output each ?? steps 100
Maximum dilution reported 100000
Text output format : Standard
Max vertical reversals : to max rise or fall

/ UM3. 6/23/2021 5:40:38 AM
Case 1; ambient file C:\Plumes20\Petersburg_1_Aug05.002.db; Diffuser table record 1: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.016	120.0	25.80	9.500	0.0	0.000195	0.016	120.0	0.0003	19.89413
9.150	0.016	120.0	28.10	8.200	0.0	0.000196	0.016	120.0	0.0003	21.86897
18.29	0.016	120.0	30.90	7.300	0.0	0.000196	0.016	120.0	0.0003	24.18118
20.00	0.016	120.0	31.42	7.132	0.0	0.000195	0.016	120.0	0.0003	24.61448

Diffuser table:

P-dia	Ver angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
4.0000	0.0	115.00	0.0	0.0	2.0000	10.000	18.300	200.00	18.070	3.6000	0.0	14.600	2.02E+6

Simulation:
Froude No: 114.5; Strat No: 7.46E-4; Spcg No: 38.41; k: 996.7; eff den (sigmaT) -0.776899; eff vel 15.95(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)	
0	18.07	1.600	3.124	2.020E+6	1.000	0.0	0.0	0.0	0.0746;	9.342 T-90hr,

100 18.07 1.600 27.00 233103.2 8.665 -0.637 1.364 0.470 0.6855; 9.340 T-90hr,
177 17.70 1.600 121.5 50815.2 39.73 -3.202 6.837 9.667 3.0831; merging; 9.198 T-90hr,
200 16.92 1.600 192.0 38804.9 51.98 -4.867 10.37 20.86 4.8693; 8.895 T-90hr,
212 15.74 1.600 258.0 32719.8 61.58 -6.629 14.10 35.23 6.5408; trap level; 8.436 T-90hr,
221 14.97 1.600 323.8 29956.8 67.21 -7.796 16.57 45.91 8.2053; MZ dis; 8.143 T-90hr,
forced entrain 1 1.914 3.095 8.224 0.970
Rate sec-1 0.00019604 dy-1 16.9376 kt: 0.000077955 Amb Sal 29.8950
Mixing Zone reached in near-field, no far-field calculation attempted
;
5:40:38 AM. amb fills: 4
/ UM3. 6/23/2021 5:40:52 AM
Case 1; ambient file C:\Plumes20\Petersburg_1_Aug05.002.db; Diffuser table record 1: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.016	120.0	25.80	9.500	0.0	0.000195	0.016	120.0	0.0003	19.89413
9.150	0.016	120.0	28.10	8.200	0.0	0.000196	0.016	120.0	0.0003	21.86897
18.29	0.016	120.0	30.90	7.300	0.0	0.000196	0.016	120.0	0.0003	24.18118
20.00	0.016	120.0	31.42	7.132	0.0	0.000195	0.016	120.0	0.0003	24.61448

Diffuser table:

P-dia	Ver angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
4.0000	0.0	115.00	0.0	0.0	2.0000	10.000	36.600	200.00	18.070	3.6000	0.0	14.600	2.02E+6

Simulation:
Froude No: 114.5; Strat No: 7.46E-4; Spcg No: 38.41; k: 996.7; eff den (sigmaT) -0.776899; eff vel 15.95(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)	
0	18.07	1.600	3.124	2.020E+6	1.000	0.0	0.0	0.0	0.07918;	9.342 T-90hr,
100	18.07	1.600	27.00	233103.2	8.665	-0.637	1.364	0.470	0.6855;	9.340 T-90hr,
177	17.70	1.600	121.5	50815.2	39.73	-3.202	6.837	9.667	3.0831;	merging; 9.198 T-90hr,
200	16.92	1.600	192.0	38804.9	51.98	-4.867	10.37	20.86	4.8693;	8.895 T-90hr,
212	15.74	1.600	258.0	32719.8	61.58	-6.629	14.10	35.23	6.5408;	trap level; 8.436 T-90hr,
269	14.43	1.600	412.1	27015.9	74.42	-9.596	20.37	63.81	10.443;	local maximum rise or fall; 7.935 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.03203; CL(m): 22.520
Lmz(m): 22.552
forced entrain 1 2.252 3.642 10.47 1.000
Rate sec-1 0.00019608 dy-1 16.9412 kt: 0.000080118 Amb Sal 29.7168
4/3 Power Law. Farfield dispersion based on wastefield width of 13.51 m

conc	dilutn	width	distnce	time	bckgrnd	decay	current	cur-dir	eddydif
(col/dl)		(m)	(m)	(hrs)	(col/dl)	(ly/hr)	(cm/s)	angle	(m0.67/s2)

27015.9 74.42 13.51 22.52 2.78E-4 0.0 16.25 1.600 120.0 3.00E-4 8.0118E-5
24577.8 89.58 21.72 36.60 0.245 0.0 16.25 1.600 120.0 3.00E-4 8.0118E-5
13316.6 149.2 37.30 59.12 0.636 0.0 16.25 1.600 120.0 3.00E-4 8.0118E-5
count: 1
;
5:40:52 AM. amb fills: 4
/ UM3. 6/23/2021 5:41:05 AM
Case 1; ambient file C:\Plumes20\Petersburg_1_Aug05.002.db; Diffuser table record 1: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.016	120.0	25.80	9.500	0.0	0.000195	0.016	120.0	0.0003	19.89413
9.150	0.016	120.0	28.10	8.200	0.0	0.000196	0.016	120.0	0.0003	21.86897
18.29	0.016	120.0	30.90	7.300	0.0	0.000196	0.016	120.0	0.0003	24.18118
20.00	0.016	120.0	31.42	7.132	0.0	0.000195	0.016	120.0	0.0003	24.61448

Diffuser table:

P-dia	Ver angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
4.0000	0.0	115.00	0.0	0.0	2.0000	10.000	91.500	200.00	18.070	3.6000	0.0	14.600	2.02E+6

Simulation:
Froude No: 114.5; Strat No: 7.46E-4; Spcg No: 38.41; k: 996.7; eff den (sigmaT) -0.776899; eff vel 15.95(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)
0	18.07	1.600	3.124	2.020E+6	1.000	0.0	0.0	0.0	0.07916; 9.342 T-90hr,
100	18.07	1.600	27.00	233103.2	8.665	-0.637	1.364	0.470	0.6855; 9.340 T-90hr,
177	17.70	1.600	121.5	50815.2	39.73	-3.202	6.837	9.667	3.0831; merging; 9.198 T-90hr,
200	16.92	1.600	192.0	38804.9	51.98	-4.867	10.37	20.86	4.8693; 8.895 T-90hr,
212	15.74	1.600	258.0	32719.8	61.58	-6.629	14.10	35.23	6.5408; trap level; 8.436 T-90hr,
269	14.43	1.600	412.1	27015.9	74.42	-9.596	20.37	63.81	10.443; local maximum rise or fall; 7.935 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.03203; CL(m): 22.520
Lmz(m): 22.552
forced entrain 1 2.252 3.642 10.47 1.000
Rate sec-1 0.00019608 dy-1 16.9412 kt: 0.000080118 Amb Sal 29.7168
4/3 Power Law. Farfield dispersion based on wastefield width of 13.51 m

conc	dilutn	width	distnce	time	bckgrnd	decay	current	cur-dir	eddydif
(col/dl)		(m)	(m)	(hrs)	(col/dl)	(ly/hr)	(cm/s)	angle	(m0.67/s2)
27015.9	74.42	13.51	22.52	2.78E-4	0.0	16.25	1.600	120.0	3.00E-4 8.0118E-5
18670.4	255.8	64.12	91.50	1.198	0.0	16.25	1.600	120.0	3.00E-4 8.0118E-5
5869.71	340.7	85.44	114.0	1.589	0.0	16.25	1.600	120.0	3.00E-4 8.0118E-5

count: 1
; 5:41:06 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
	4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	74.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	13.51	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	22.52	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	91.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.016	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	2.70E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 9.6530E-03 m^2/s
Beta = 5.3588E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	1.197569444	68.98	91.5	2.56E+02	7.86E+03	257

```
/ UM3. 6/23/2021 5:41:17 AM
Case 1; ambient file C:\Plumes20\Petersburg_1_Aug05.002.db; Diffuser table record 1: ---------------------
-------------

Ambient Table:
    Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
       m      m/s      deg      psu       C     kg/kg      s-1      m/s      deg  m0.67/s2   sigma-T
     0.0    0.016    120.0    25.80    9.500      0.0  0.000195    0.016    120.0   0.0003  19.89413
   9.150    0.016    120.0    28.10    8.200      0.0  0.000196    0.016    120.0   0.0003  21.86897
   18.29    0.016    120.0    30.90    7.300      0.0  0.000196    0.016    120.0   0.0003  24.18118
   20.00    0.016    120.0    31.42    7.132      0.0  0.000195    0.016    120.0   0.0003  24.61448

Diffuser table:
  P-diaVer angl H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
   (in)  (deg)  (deg)    (m)    (m)     ()   (ft)    (m)(concent)    (m)  (MGD)  (psu)     (C)(col/dl)
  4.0000     0.0  115.00     0.0     0.0  2.0000  10.000  183.00  200.00  18.070  3.6000     0.0  14.600
2.02E+6

Simulation:
Froude No:     114.5; Strat No: 7.46E-4; Spcg No:   38.41; k:   996.7; eff den (sigmaT) -0.776899; eff vel
15.95(m/s);
       Depth  Amb-cur    P-dia  Polutnt   Dilutn   x-posn   y-posn     Time   Iso dia
Step     (m)   (cm/s)     (in) (col/dl)       ()      (m)      (m)      (s)       (m)
  0     18.07    1.600    3.124 2.020E+6    1.000      0.0      0.0      0.0   0.07916;  9.342 T-90hr,
 100    18.07    1.600    27.00 233103.2    8.665   -0.637    1.364    0.470    0.6855;  9.340 T-90hr,
 177    17.70    1.600    121.5  50815.2    39.73   -3.202    6.837    9.667    3.0831; merging;  9.198 T-90hr,
 200    16.92    1.600    192.0  38804.9    51.98   -4.867    10.37    20.86    4.8693;  8.895 T-90hr,
 212    15.74    1.600    258.0  32719.8    61.58   -6.629    14.10    35.23    6.5408; trap level;  8.436 T-
90hr,
 269    14.43    1.600    412.1  27015.9    74.42   -9.596    20.37    63.81    10.443; local maximum rise or
fall;  7.935 T-90hr,
Horiz plane projections in effluent direction: radius(m):  0.03203; CL(m):   22.520
Lmz(m):   22.552
forced entrain      1   2.252   3.642   10.47   1.000
Rate sec-1   0.00019608 dy-1      16.9412  kt:  0.000080118 Amb Sal      29.7168
4/3 Power Law.  Farfield dispersion based on wastefield width of      13.51 m
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)            (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 27015.9   74.42   13.51   22.52 2.78E-4     0.0   16.25   1.600   120.0 3.00E-4 8.0118E-5
 11807.9   646.9   162.2   183.0   2.786     0.0   16.25   1.600   120.0 3.00E-4 8.0118E-5
 2638.61   760.1   190.6   205.5   3.177     0.0   16.25   1.600   120.0 3.00E-4 8.0118E-5
count: 1
 ;
5:41:17 AM. amb fills: 4
```

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
	4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	74.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	13.51	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	22.52	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	183	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.016	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	2.70E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 9.6530E-03 m^2/s
Beta = 5.3588E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	2.786111111	160.48	183	6.47E+02	3.11E+03	650

Sitka (model output for 1*depth, 2*depth, 5*depth and 10*depth)

Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Sitka" memo

Model configuration items checked: Brooks far-field solution; Report effective dilution; ;
Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
Bacteria model : Mancini (1978) coliform model
PDS sfc. model heat transfer : Medium
Equation of State : S, T
Similarity Profile : Default profile (k=2.0, ...)
Diffuser port contraction coefficient 1
Light absorption coefficient 0.16
Farfield increment (m) 100
UM3 aspiration coefficient 0.1
Output file: text output tab
Output each ?? steps 100
Maximum dilution reported 100000
Text output format : Standard
Max vertical reversals : to max rise or fall

/ uDKHLRD; for extra details examine output file \Plumes20\dkhwisp.out
Case 1; ambient file C:\Plumes20\Sitka_C_Jul10.005.db; Diffuser table record 2: ---------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.017	225.0	26.60	12.70	0.0	0.000196	0.017	225.0	0.0003	19.98988
1.000	0.017	225.0	26.60	12.70	0.0	0.000198	0.017	225.0	0.0003	19.98988
5.000	0.017	225.0	28.20	12.20	0.0	0.000198	0.017	225.0	0.0003	21.31369
10.00	0.017	225.0	29.10	11.60	0.0	0.000198	0.017	225.0	0.0003	22.11543
15.00	0.017	225.0	29.60	10.60	0.0	0.000197	0.017	225.0	0.0003	22.67329
20.00	0.017	225.0	29.80	9.800	0.0	0.000197	0.017	225.0	0.0003	22.95817
25.00	0.017	225.0	29.90	9.500	0.0	0.000196	0.017	225.0	0.0003	23.08290
30.00	0.017	225.0	29.90	9.100	0.0	0.000196	0.017	225.0	0.0003	23.14401

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
4.0000	0.0	300.00	0.0	0.0	16.000	13.000	24.400	200.00	23.940	5.3000	0.0	15.000	3.74E+6

Simulation:

Froude No: 11.60; Strat No: 5.45E-4; Spcg No: 39.00; k: 105.3; eff den (sigmaT) -0.836341; eff vel 1.790(m/s);

Step	Depth (m)	Amb-cur (cm/s)	P-dia (in)	Polutnt (col/dl)	net Dil ()	x-posn (m)	y-posn (m)	Time (s)	Iso dia (m)
0	23.94	1.700	4.000	3.740E+6	0.0	0.0	0.0	0.0	0.1014; 11.44 T-90hr,
1	23.94	1.700	4.000	3.740E+6	1.000	0.0	0.0	0.0	0.1016; 11.44 T-90hr,
2	23.93	1.700	10.94	1.929E+6	1.939	-0.497	0.285	0.320	0.2780; 11.43 T-90hr,
3	23.92	1.700	14.30	1.472E+6	2.540	-0.585	0.334	0.385	0.3632; 11.43 T-90hr,
5	23.90	1.700	21.15	988111.0	3.785	-0.763	0.432	0.566	0.5372; 11.42 T-90hr,
7	23.87	1.700	28.20	733621.0	5.098	-0.940	0.527	0.820	0.7162; 11.41 T-90hr,
9	23.80	1.700	38.91	519516.6	7.199	-1.202	0.662	1.331	0.9883; 11.38 T-90hr,
11	23.64	1.700	52.78	364415.9	10.26	-1.539	0.825	2.240	1.3405; 11.32 T-90hr,
13	23.42	1.700	63.65	283591.1	13.19	-1.848	0.963	3.349	1.6165; merging; 11.24 T-90hr,
17	22.83	1.700	76.78	206140.1	18.14	-2.365	1.164	5.764	1.9498; 11.01 T-90hr,
21	22.14	1.700	87.81	163240.4	22.91	-2.776	1.297	8.271	2.2298; 10.75 T-90hr,
27	21.03	1.700	104.8	125663.6	29.76	-3.270	1.419	12.28	2.6616; 10.33 T-90hr,
55	19.66	1.700	131.6	99789.2	37.48	-3.747	1.497	17.53	3.3416; 9.805 T-90hr,
67	17.85	1.700	164.7	79160.1	47.25	-4.268	1.537	24.48	4.1811; 9.113 T-90hr,
79	15.49	1.700	218.5	62651.8	59.70	-4.873	1.525	33.78	5.5450; 8.222 T-90hr,
133	12.24	1.700	351.2	49337.1	75.81	-5.704	1.423	48.38	8.9048; 7.033 T-90hr,
151	9.808	1.700	947.0	43327.2	86.32	-6.744	1.206	68.20	24.008; 6.180 T-90hr,

4/3 Power Law. Farfield dispersion based on wastefield width of 83.49 m

conc (col/dl)	dilutn	width (m)	distnce (m)	time (hrs)	bckgrnd (col/dl)	decay (ly/hr)	current (cm/s)	cur-dir angle	eddydif (m0.67/s2)	
43327.2	86.32	83.51	6.851	2.78E-4	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5
3.53E+6	87.12	100.3	24.40	0.287	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5
9.94E+5	89.08	107.1	31.25	0.399	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5

count: 1

;

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	86.32	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	83.49	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	6.851	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	24.4	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	1.31E-03	
4. Horizontal current speed (m/sec)	0.017	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	4.33E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 1.0947E-01 m^2/s
Beta = 9.2555E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	2.87E-01	17.549	24.40	8.70E+01	4.30E+04	87

/ uDKHLRD; for extra details examine output file \Plumes20\dkhwisp.out
Case 1; ambient file C:\Plumes20\Sitka_C_Jul10.005.db; Diffuser table record 2: ---------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.017	225.0	26.60	12.70	0.0	0.000196	0.017	225.0	0.0003	19.98988
1.000	0.017	225.0	26.60	12.70	0.0	0.000198	0.017	225.0	0.0003	19.98988
5.000	0.017	225.0	28.20	12.20	0.0	0.000198	0.017	225.0	0.0003	21.31369
10.00	0.017	225.0	29.10	11.60	0.0	0.000198	0.017	225.0	0.0003	22.11543
15.00	0.017	225.0	29.60	10.60	0.0	0.000197	0.017	225.0	0.0003	22.67329
20.00	0.017	225.0	29.80	9.800	0.0	0.000197	0.017	225.0	0.0003	22.95817
25.00	0.017	225.0	29.90	9.500	0.0	0.000196	0.017	225.0	0.0003	23.08290
30.00	0.017	225.0	29.90	9.100	0.0	0.000196	0.017	225.0	0.0003	23.14401

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
4.0000	0.0	300.00	0.0	0.0	16.000	13.000	48.800	200.00	23.940	5.3000	0.0	15.000	3.74E+6

Simulation:
Froude No: 11.60; Strat No: 5.45E-4; Spcg No: 39.00; k: 105.3; eff den (sigmaT) -0.836341; eff vel 1.790(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	net Dil	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)	
0	23.94	1.700	4.000	3.740E+6	1.000	0.0	0.0	0.0	0.1014;	11.44 T-90hr,
1	23.94	1.700	4.000	3.740E+6	1.000	0.0	0.0	0.0	0.1016;	11.44 T-90hr,
2	23.93	1.700	10.94	1.929E+6	1.939	-0.497	0.285	0.320	0.2780;	11.43 T-90hr,
3	23.92	1.700	14.30	1.472E+6	2.540	-0.585	0.334	0.385	0.3632;	11.43 T-90hr,
5	23.90	1.700	21.15	988111.0	3.785	-0.763	0.432	0.566	0.5372;	11.42 T-90hr,
7	23.87	1.700	28.20	733621.0	5.098	-0.940	0.527	0.820	0.7162;	11.41 T-90hr,
9	23.80	1.700	38.91	519516.6	7.199	-1.202	0.662	1.331	0.9883;	11.38 T-90hr,
11	23.64	1.700	52.78	364415.9	10.26	-1.539	0.825	2.240	1.3405;	11.32 T-90hr,
13	23.42	1.700	63.65	283591.1	13.19	-1.848	0.963	3.349	1.6165;	merging; 11.24 T-90hr,
17	22.83	1.700	76.78	206140.1	18.14	-2.365	1.164	5.764	1.9498;	11.01 T-90hr,
21	22.14	1.700	87.81	163240.4	22.91	-2.776	1.297	8.271	2.2298;	10.75 T-90hr,
27	21.03	1.700	104.8	125663.6	29.76	-3.270	1.419	12.28	2.6616;	10.33 T-90hr,
55	19.66	1.700	131.6	99789.2	37.48	-3.747	1.497	17.53	3.3416;	9.805 T-90hr,
67	17.85	1.700	164.7	79160.1	47.25	-4.268	1.537	24.48	4.1811;	9.113 T-90hr,
79	15.49	1.700	218.5	62651.8	59.70	-4.873	1.525	33.78	5.5450;	8.222 T-90hr,
133	12.24	1.700	351.2	49337.1	75.81	-5.704	1.423	48.38	8.9048;	7.033 T-90hr,
151	9.808	1.700	947.0	43327.2	86.32	-6.744	1.206	68.20	24.008;	6.180 T-90hr,

4/3 Power Law. Farfield dispersion based on wastefield width of 83.49 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
43327.2 86.32 83.51 6.851 2.78E-4 0.0 8.000 1.700 225.0 3.00E-4 5.5441E-5

3.26E+6	98.22	125.2	48.80	0.686	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5
2.14E+5	102.8	132.5	55.65	0.798	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5

count: 1
;

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	86.32	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	83.49	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	6.851	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	48.8	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	1.31E-03	
4. Horizontal current speed (m/sec)	0.017	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	4.33E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 1.0947E-01 m^2/s
Beta = 9.2555E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	6.85E-01	41.949	48.80	9.65E+01	3.87E+04	97

/ uDKHLRD; for extra details examine output file \Plumes20\dkhwisp.out
Case 1; ambient file C:\Plumes20\Sitka_C_Jul10.005.db; Diffuser table record 2: -----------------------------
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Ambient Table:
Depth Amb-cur Amb-dir Amb-sal Amb-tem Amb-pol Solar rad Far-spd Far-dir Disprsn
Density
m m/s deg psu C kg/kg s-1 m/s deg m0.67/s2 sigma-T
0.0 0.017 225.0 26.60 12.70 0.0 0.000196 0.017 225.0 0.0003 19.98988
1.000 0.017 225.0 26.60 12.70 0.0 0.000198 0.017 225.0 0.0003 19.98988
5.000 0.017 225.0 28.20 12.20 0.0 0.000198 0.017 225.0 0.0003 21.31369
10.00 0.017 225.0 29.10 11.60 0.0 0.000198 0.017 225.0 0.0003 22.11543
15.00 0.017 225.0 29.60 10.60 0.0 0.000197 0.017 225.0 0.0003 22.67329
20.00 0.017 225.0 29.80 9.800 0.0 0.000197 0.017 225.0 0.0003 22.95817
25.00 0.017 225.0 29.90 9.500 0.0 0.000196 0.017 225.0 0.0003 23.08290
30.00 0.017 225.0 29.90 9.100 0.0 0.000196 0.017 225.0 0.0003 23.14401

Diffuser table:
P-dia VertAng H-Angle SourceX SourceY Ports Spacing MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
(in) (deg) (deg) (m) (m) () (ft) (m)(concent) (m) (MGD) (psu) (C)(col/dl)
4.0000 0.0 300.00 0.0 0.0 16.000 13.000 122.00 200.00 23.940 5.3000 0.0 15.000
3.74E+6

Simulation:
Froude No: 11.60; Strat No: 5.45E-4; Spcg No: 39.00; k: 105.3; eff den (sigmaT) -0.836341; eff vel
1.790(m/s);
Depth Amb-cur P-dia Polutnt net Dil x-posn y-posn Time Iso dia
Step (m) (cm/s) (in) (col/dl) () (m) (m) (s) (m)
0 23.94 1.700 4.000 3.740E+6 1.000 0.0 0.0 0.0 0.1014; 11.44 T-90hr,
1 23.94 1.700 4.000 3.740E+6 1.000 0.0 0.0 0.0 0.1016; 11.44 T-90hr,
2 23.93 1.700 10.94 1.929E+6 1.939 -0.497 0.285 0.320 0.2780; 11.43 T-90hr,
3 23.92 1.700 14.30 1.472E+6 2.540 -0.585 0.334 0.385 0.3632; 11.43 T-90hr,
5 23.90 1.700 21.15 988111.0 3.785 -0.763 0.432 0.566 0.5372; 11.42 T-90hr,
7 23.87 1.700 28.20 733621.0 5.098 -0.940 0.527 0.820 0.7162; 11.41 T-90hr,
9 23.80 1.700 38.91 519516.6 7.199 -1.202 0.662 1.331 0.9883; 11.38 T-90hr,
11 23.64 1.700 52.78 364415.9 10.26 -1.539 0.825 2.240 1.3405; 11.32 T-90hr,
13 23.42 1.700 63.65 283591.1 13.19 -1.848 0.963 3.349 1.6165; merging; 11.24 T-90hr,
17 22.83 1.700 76.78 206140.1 18.14 -2.365 1.164 5.764 1.9498; 11.01 T-90hr,
21 22.14 1.700 87.81 163240.4 22.91 -2.776 1.297 8.271 2.2298; 10.75 T-90hr,
27 21.03 1.700 104.8 125663.6 29.76 -3.270 1.419 12.28 2.6616; 10.33 T-90hr,
55 19.66 1.700 131.6 99789.2 37.48 -3.747 1.497 17.53 3.3416; 9.805 T-90hr,
67 17.85 1.700 164.7 79160.1 47.25 -4.268 1.537 24.48 4.1811; 9.113 T-90hr,
79 15.49 1.700 218.5 62651.8 59.70 -4.873 1.525 33.78 5.5450; 8.222 T-90hr,
133 12.24 1.700 351.2 49337.1 75.81 -5.704 1.423 48.38 8.9048; 7.033 T-90hr,
151 9.808 1.700 947.0 43327.2 86.32 -6.744 1.206 68.20 24.008; 6.180 T-90hr,
4/3 Power Law. Farfield dispersion based on wastefield width of 83.49 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
43327.2 86.32 83.51 6.851 2.78E-4 0.0 8.000 1.700 225.0 3.00E-4 5.5441E-5
2.76E+6 138.1 183.2 100.0 1.522 0.0 8.000 1.700 225.0 3.00E-4 5.5441E-5

46877.1	236.4	315.8	200.0	3.156	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5
23592.2	243.8	325.7	206.9	3.268	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5

count: 2
;

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	86.32	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	83.49	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	6.851	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	122	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	1.31E-03	
4. Horizontal current speed (m/sec)	0.017	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	4.33E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 1.0947E-01 m^2/s
Beta = 9.2555E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	1.88E+00	115.149	122.00	1.43E+02	2.61E+04	143

/ uDKHLRD; for extra details examine output file \Plumes20\dkhwisp.out
Case 1; ambient file C:\Plumes20\Sitka_C_Jul10.005.db; Diffuser table record 2: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.017	225.0	26.60	12.70	0.0	0.000196	0.017	225.0	0.0003	19.98988
1.000	0.017	225.0	26.60	12.70	0.0	0.000198	0.017	225.0	0.0003	19.98988
5.000	0.017	225.0	28.20	12.20	0.0	0.000198	0.017	225.0	0.0003	21.31369
10.00	0.017	225.0	29.10	11.60	0.0	0.000198	0.017	225.0	0.0003	22.11543
15.00	0.017	225.0	29.60	10.60	0.0	0.000197	0.017	225.0	0.0003	22.67329
20.00	0.017	225.0	29.80	9.800	0.0	0.000197	0.017	225.0	0.0003	22.95817
25.00	0.017	225.0	29.90	9.500	0.0	0.000196	0.017	225.0	0.0003	23.08290
30.00	0.017	225.0	29.90	9.100	0.0	0.000196	0.017	225.0	0.0003	23.14401

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
4.0000	0.0	300.00	0.0	0.0	16.000	13.000	244.00	200.00	23.940	5.3000	0.0	15.000	3.74E+6

Simulation:
Froude No: 11.60; Strat No: 5.45E-4; Spcg No: 39.00; k: 105.3; eff den (sigmaT) -0.836341; eff vel 1.790(m/s);

Step	Depth (m)	Amb-cur (cm/s)	P-dia (in)	Polutnt (col/dl)	net Dil ()	x-posn (m)	y-posn (m)	Time (s)	Iso dia (m)	
0	23.94	1.700	4.000	3.740E+6	1.000	0.0	0.0	0.0	0.1014;	11.44 T-90hr,
1	23.94	1.700	4.000	3.740E+6	1.000	0.0	0.0	0.0	0.1016;	11.44 T-90hr,
2	23.93	1.700	10.94	1.929E+6	1.939	-0.497	0.285	0.320	0.2780;	11.43 T-90hr,
3	23.92	1.700	14.30	1.472E+6	2.540	-0.585	0.334	0.385	0.3632;	11.43 T-90hr,
5	23.90	1.700	21.15	988111.0	3.785	-0.763	0.432	0.566	0.5372;	11.42 T-90hr,
7	23.87	1.700	28.20	733621.0	5.098	-0.940	0.527	0.820	0.7162;	11.41 T-90hr,
9	23.80	1.700	38.91	519516.6	7.199	-1.202	0.662	1.331	0.9883;	11.38 T-90hr,
11	23.64	1.700	52.78	364415.9	10.26	-1.539	0.825	2.240	1.3405;	11.32 T-90hr,
13	23.42	1.700	63.65	283591.1	13.19	-1.848	0.963	3.349	1.6165;	merging; 11.24 T-90hr,
17	22.83	1.700	76.78	206140.1	18.14	-2.365	1.164	5.764	1.9498;	11.01 T-90hr,
21	22.14	1.700	87.81	163240.4	22.91	-2.776	1.297	8.271	2.2298;	10.75 T-90hr,
27	21.03	1.700	104.8	125663.6	29.76	-3.270	1.419	12.28	2.6616;	10.33 T-90hr,
55	19.66	1.700	131.6	99789.2	37.48	-3.747	1.497	17.53	3.3416;	9.805 T-90hr,
67	17.85	1.700	164.7	79160.1	47.25	-4.268	1.537	24.48	4.1811;	9.113 T-90hr,
79	15.49	1.700	218.5	62651.8	59.70	-4.873	1.525	33.78	5.5450;	8.222 T-90hr,
133	12.24	1.700	351.2	49337.1	75.81	-5.704	1.423	48.38	8.9048;	7.033 T-90hr,
151	9.808	1.700	947.0	43327.2	86.32	-6.744	1.206	68.20	24.008;	6.180 T-90hr,

4/3 Power Law. Farfield dispersion based on wastefield width of 83.49 m

conc	dilutn	width	distnce	time	bckgrnd	decay	current	cur-dir	eddydif	
(col/dl)		(m)	(m)	(hrs)	(col/dl)	(ly/hr)	(cm/s)	angle	(m0.67/s2)	
43327.2	86.32	83.51	6.851	2.78E-4	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5
2.76E+6	138.1	183.2	100.0	1.522	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5

46877.1	236.4	315.8	200.0	3.156	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5
17411.5	352.0	470.5	300.0	4.790	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5
13591.4	360.5	481.8	306.9	4.902	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5

count: 3

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	86.32	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	83.49	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	6.851	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	244	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	1.31E-03	
4. Horizontal current speed (m/sec)	0.017	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	4.33E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 1.0947E-01 m^2/s
Beta = 9.2555E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	3.87E+00	237.149	244.00	2.27E+02	1.65E+04	227

Skagway (model output for 1*depth, 2*depth, 5*depth and 10*depth)

Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Skagway" memo

Model configuration items checked: Brooks far-field solution;
Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
Bacteria model : Mancini (1978) coliform model
PDS sfc. model heat transfer : Medium
Equation of State : S, T
Similarity Profile : Default profile (k=2.0, ...)
Diffuser port contraction coefficient 0.61
Light absorption coefficient 0.16
Farfield increment (m) 200
UM3 aspiration coefficient 0.1
Output file: text output tab
Output each ?? steps 100
Maximum dilution reported 100000
Text output format : Standard
Max vertical reversals : to max rise or fall

/ UM3. 6/23/2021 5:51:09 AM
Case 1; ambient file C:\Plumes20\Skagway_1_Jun05.005.db; Diffuser table record 2: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.014	350.0	7.100	11.12	0.0	0.000194	0.014	350.0	0.0003	5.180276
1.523	0.014	350.0	14.16	10.08	0.0	0.000197	0.014	350.0	0.0003	10.78304
3.047	0.014	350.0	23.30	8.650	0.0	0.000197	0.014	350.0	0.0003	18.06627
4.570	0.014	350.0	23.25	8.670	0.0	0.000196	0.014	350.0	0.0003	18.02474
6.090	0.014	350.0	25.20	8.220	0.0	0.000196	0.014	350.0	0.0003	19.60292
7.617	0.014	350.0	26.37	8.020	0.0	0.000196	0.014	350.0	0.0003	20.54204
9.140	0.014	350.0	26.74	7.980	0.0	0.000195	0.014	350.0	0.0003	20.83621
10.45	0.014	350.0	27.46	7.570	0.0	0.000195	0.014	350.0	0.0003	21.45192
11.75	0.014	350.0	28.24	7.100	0.0	0.000195	0.014	350.0	0.0003	22.12180
13.06	0.014	350.0	28.92	6.920	0.0	0.000195	0.014	350.0	0.0003	22.67724
14.37	0.014	350.0	29.08	6.880	0.0	0.000195	0.014	350.0	0.0003	22.80770
15.68	0.014	350.0	29.29	6.790	0.0	0.000195	0.014	350.0	0.0003	22.98359
16.98	0.014	350.0	30.42	6.260	0.0	0.000195	0.014	350.0	0.0003	23.93584
20.00	0.014	350.0	33.05	5.029	0.0	0.000195	0.014	350.0	0.0003	26.14924

Diffuser table:
P-dia VertAng H-Angle SourceX SourceY Ports Spacing MZ-dis Isoplth P-depth Ttl-flo Eff-sal Temp Polutnt

(in) (deg) (deg) (m) (m) () (ft) (m)(concent) (m) (MGD) (psu) (C)(col/dl)
3.0000 0.0 350.00 0.0 0.0 8.0000 3.5000 18.300 200.00 18.150 0.6300 0.0 17.300
2.59E+6

Simulation:
Froude No: 10.06; Strat No: 2.47E-3; Spcg No: 17.93; k: 88.59; eff den (sigmaT) -1.214163; eff vel 1.240(m/s);
Depth Amb-cur P-dia Polutnt Dilutn x-posn y-posn Time Iso dia
Step (m) (cm/s) (in) (col/dl) () (m) (m) (s) (m)
0 18.15 1.400 2.343 2.590E+6 1.000 0.0 0.0 0.0 0.0594; 9.458 T-90hr,
100 18.07 1.400 12.32 471750.7 5.490 0.639 -0.113 1.673 0.3130; 9.424 T-90hr,
200 17.61 1.400 21.87 219905.3 11.77 1.318 -0.232 6.056 0.5554; 9.240 T-90hr,
267 16.05 1.400 42.65 85238.4 30.34 2.296 -0.405 19.44 1.0826; trap level, merging; 8.615 T-90hr,
300 15.34 1.400 63.27 67833.1 38.10 2.732 -0.482 28.58 1.6057; 8.339 T-90hr,
318 15.20 1.400 71.39 65187.4 39.64 2.853 -0.503 31.31 1.8117; begin overlap; 8.285 T-90hr,
400 14.95 1.400 94.95 62151.2 41.55 3.192 -0.563 39.26 2.4091; 8.187 T-90hr,
480 14.90 1.400 102.6 61721.1 41.83 3.409 -0.601 44.43 2.6036; local maximum rise or fall; 8.170 T-90hr,
Horiz plane projections in effluent direction: radius(m): 0.0000; CL(m): 3.4620
Lmz(m): 3.4620
forced entrain 1 14.06 3.247 2.606 1.000
Rate sec-1 0.00019534 dy-1 16.8772 kt: 0.000078146 Amb Sal 29.1654
4/3 Power Law. Farfield dispersion based on wastefield width of 10.07 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
61721.1 41.83 10.08 3.462 2.78E-4 0.0 16.30 1.400 350.0 3.00E-4 7.8146E-5
55457.0 59.02 19.36 18.30 0.295 0.0 16.30 1.400 350.0 3.00E-4 7.8146E-5
38485.5 66.05 21.80 21.76 0.363 0.0 16.30 1.400 350.0 3.00E-4 7.8146E-5
count: 1
;
5:51:09 AM. amb fills: 4

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)		
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	41.83	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	10.07	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	3.462	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	18.3	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.48E-04	
4. Horizontal current speed (m/sec)	0.014	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	6.17E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.5237E-03 m^2/s
Beta = 5.5529E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	2.94E-01	14.838	18.30	5.61E+01	4.60E+04	56

/ UM3. 6/23/2021 5:51:23 AM
Case 1; ambient file C:\Plumes20\Skagway_1_Jun05.005.db; Diffuser table record 2: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.014	350.0	7.100	11.12	0.0	0.000194	0.014	350.0	0.0003	5.180276
1.523	0.014	350.0	14.16	10.08	0.0	0.000197	0.014	350.0	0.0003	10.78304
3.047	0.014	350.0	23.30	8.650	0.0	0.000197	0.014	350.0	0.0003	18.06627
4.570	0.014	350.0	23.25	8.670	0.0	0.000196	0.014	350.0	0.0003	18.02474
6.090	0.014	350.0	25.20	8.220	0.0	0.000196	0.014	350.0	0.0003	19.60292
7.617	0.014	350.0	26.37	8.020	0.0	0.000196	0.014	350.0	0.0003	20.54204
9.140	0.014	350.0	26.74	7.980	0.0	0.000196	0.014	350.0	0.0003	20.83621
10.45	0.014	350.0	27.46	7.570	0.0	0.000195	0.014	350.0	0.0003	21.45192
11.75	0.014	350.0	28.24	7.100	0.0	0.000195	0.014	350.0	0.0003	22.12180
13.06	0.014	350.0	28.92	6.920	0.0	0.000195	0.014	350.0	0.0003	22.67724
14.37	0.014	350.0	29.08	6.880	0.0	0.000195	0.014	350.0	0.0003	22.80770
15.68	0.014	350.0	29.29	6.790	0.0	0.000195	0.014	350.0	0.0003	22.98359
16.98	0.014	350.0	30.42	6.260	0.0	0.000195	0.014	350.0	0.0003	23.93584
20.00	0.014	350.0	33.05	5.029	0.0	0.000195	0.014	350.0	0.0003	26.14924

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.0000	0.0	350.00	0.0	0.0	8.0000	3.5000	36.600	200.00	18.150	0.6300	0.0	17.300	2.59E+6

Simulation:
Froude No: 10.06; Strat No: 2.47E-3; Spcg No: 17.93; k: 88.59; eff den (sigmaT) -1.214163; eff vel 1.240(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)
0	18.15	1.400	2.343	2.590E+6	1.000	0.0	0.0	0.0	0.05945; 9.458 T-90hr,
100	18.07	1.400	12.32	471750.7	5.490	0.639	-0.113	1.673	0.3130; 9.424 T-90hr,
200	17.61	1.400	21.87	219905.3	11.77	1.318	-0.232	6.056	0.5554; 9.240 T-90hr,
267	16.05	1.400	42.65	85238.4	30.34	2.296	-0.405	19.44	1.0826; trap level, merging; 8.615 T-90hr,
300	15.34	1.400	63.27	67833.1	38.10	2.732	-0.482	28.58	1.6057; 8.339 T-90hr,
318	15.20	1.400	71.39	65187.4	39.64	2.853	-0.503	31.31	1.8117; begin overlap; 8.285 T-90hr,
400	14.95	1.400	94.95	62151.2	41.55	3.192	-0.563	39.26	2.4091; 8.187 T-90hr,
480	14.90	1.400	102.6	61721.1	41.83	3.409	-0.601	44.43	2.6036; local maximum rise or fall; 8.170 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0000; CL(m): 3.4620
Lmz(m): 3.4620

forced entrain 1 14.06 3.247 2.606 1.000
Rate sec-1 0.00019534 dy-1 16.8772 kt: 0.000078146 Amb Sal 29.1654
4/3 Power Law. Farfield dispersion based on wastefield width of 10.07 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
61721.1 41.83 10.08 3.462 2.78E-4 0.0 16.30 1.400 350.0 3.00E-4 7.8146E-5
50071.9 100.1 33.29 36.60 0.658 0.0 16.30 1.400 350.0 3.00E-4 7.8146E-5
23499.3 108.8 36.19 40.06 0.726 0.0 16.30 1.400 350.0 3.00E-4 7.8146E-5
count: 1
;
5:51:23 AM. amb fills: 4

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	41.83	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	10.07	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	3.462	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	36.6	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.48E-04	
4. Horizontal current speed (m/sec)	0.014	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	6.17E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.5237E-03 m^2/s
Beta = 5.5529E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	6.58E-01	33.138	36.60	8.58E+01	3.01E+04	86

/ UM3. 6/23/2021 5:51:35 AM
Case 1; ambient file C:\Plumes20\Skagway_1_Jun05.005.db; Diffuser table record 2: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.014	350.0	7.100	11.12	0.0	0.000194	0.014	350.0	0.0003	5.180276
1.523	0.014	350.0	14.16	10.08	0.0	0.000197	0.014	350.0	0.0003	10.78304
3.047	0.014	350.0	23.30	8.650	0.0	0.000197	0.014	350.0	0.0003	18.06627
4.570	0.014	350.0	23.25	8.670	0.0	0.000196	0.014	350.0	0.0003	18.02474
6.090	0.014	350.0	25.20	8.220	0.0	0.000196	0.014	350.0	0.0003	19.60292
7.617	0.014	350.0	26.37	8.020	0.0	0.000196	0.014	350.0	0.0003	20.54204
9.140	0.014	350.0	26.74	7.980	0.0	0.000196	0.014	350.0	0.0003	20.83621
10.45	0.014	350.0	27.46	7.570	0.0	0.000195	0.014	350.0	0.0003	21.45192
11.75	0.014	350.0	28.24	7.100	0.0	0.000195	0.014	350.0	0.0003	22.12180
13.06	0.014	350.0	28.92	6.920	0.0	0.000195	0.014	350.0	0.0003	22.67724
14.37	0.014	350.0	29.08	6.880	0.0	0.000195	0.014	350.0	0.0003	22.80770
15.68	0.014	350.0	29.29	6.790	0.0	0.000195	0.014	350.0	0.0003	22.98359
16.98	0.014	350.0	30.42	6.260	0.0	0.000195	0.014	350.0	0.0003	23.93584
20.00	0.014	350.0	33.05	5.029	0.0	0.000195	0.014	350.0	0.0003	26.14924

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.0000	0.0	350.00	0.0	0.0	8.0000	3.5000	91.500	200.00	18.150	0.6300	0.0	17.300	2.59E+6

Simulation:
Froude No: 10.06; Strat No: 2.47E-3; Spcg No: 17.93; k: 88.59; eff den (sigmaT) -1.214163; eff vel 1.240(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)
0	18.15	1.400	2.343	2.590E+6	1.000	0.0	0.0	0.0	0.05945; 9.458 T-90hr,
100	18.07	1.400	12.32	471750.7	5.490	0.639	-0.113	1.673	0.3130; 9.424 T-90hr,
200	17.61	1.400	21.87	219905.3	11.77	1.318	-0.232	6.056	0.5554; 9.240 T-90hr,
267	16.05	1.400	42.65	85238.4	30.34	2.296	-0.405	19.44	1.0826; trap level, merging; 8.615 T-90hr,
300	15.34	1.400	63.27	67833.1	38.10	2.732	-0.482	28.58	1.6057; 8.339 T-90hr,
318	15.20	1.400	71.39	65187.4	39.64	2.853	-0.503	31.31	1.8117; begin overlap; 8.285 T-90hr,
400	14.95	1.400	94.95	62151.2	41.55	3.192	-0.563	39.26	2.4091; 8.187 T-90hr,
480	14.90	1.400	102.6	61721.1	41.83	3.409	-0.601	44.43	2.6036; local maximum rise or fall; 8.170 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0000; CL(m): 3.4620
Lmz(m): 3.4620
forced entrain 1 14.06 3.247 2.606 1.000
Rate sec-1 0.00019534 dy-1 16.8772 kt: 0.000078146 Amb Sal 29.1654
4/3 Power Law. Farfield dispersion based on wastefield width of 10.07 m

```
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)          (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 61721.1   41.83   10.08   3.462 2.78E-4    0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
 36855.9   263.9   87.83   91.50   1.747    0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
 9323.75   275.8   91.82   94.96   1.816    0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
count: 1
 ;
5:51:35 AM. amb fills: 4
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	41.83	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	10.07	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	3.462	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	91.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.48E-04	
4. Horizontal current speed (m/sec)	0.014	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	6.17E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT						
			Eo = 6.5237E-03 m^2/s			
			Beta = 5.5529E-01 unitless			
	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	1.75E+00	88.038	91.50	1.77E+02	1.46E+04	178

/ UM3. 6/23/2021 5:51:47 AM
Case 1; ambient file C:\Plumes20\Skagway_1_Jun05.005.db; Diffuser table record 2: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.014	350.0	7.100	11.12	0.0	0.000194	0.014	350.0	0.0003	5.180276
1.523	0.014	350.0	14.16	10.08	0.0	0.000197	0.014	350.0	0.0003	10.78304
3.047	0.014	350.0	23.30	8.650	0.0	0.000197	0.014	350.0	0.0003	18.06627
4.570	0.014	350.0	23.25	8.670	0.0	0.000196	0.014	350.0	0.0003	18.02474
6.090	0.014	350.0	25.20	8.220	0.0	0.000196	0.014	350.0	0.0003	19.60292
7.617	0.014	350.0	26.37	8.020	0.0	0.000196	0.014	350.0	0.0003	20.54204
9.140	0.014	350.0	26.74	7.980	0.0	0.000196	0.014	350.0	0.0003	20.83621
10.45	0.014	350.0	27.46	7.570	0.0	0.000195	0.014	350.0	0.0003	21.45192
11.75	0.014	350.0	28.24	7.100	0.0	0.000195	0.014	350.0	0.0003	22.12180
13.06	0.014	350.0	28.92	6.920	0.0	0.000195	0.014	350.0	0.0003	22.67724
14.37	0.014	350.0	29.08	6.880	0.0	0.000195	0.014	350.0	0.0003	22.80770
15.68	0.014	350.0	29.29	6.790	0.0	0.000195	0.014	350.0	0.0003	22.98359
16.98	0.014	350.0	30.42	6.260	0.0	0.000195	0.014	350.0	0.0003	23.93584
20.00	0.014	350.0	33.05	5.029	0.0	0.000195	0.014	350.0	0.0003	26.14924

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.0000	0.0	350.00	0.0	0.0	8.0000	3.5000	183.00	200.00	18.150	0.6300	0.0	17.300	2.59E+6

Simulation:
Froude No: 10.06; Strat No: 2.47E-3; Spcg No: 17.93; k: 88.59; eff den (sigmaT) -1.214163; eff vel 1.240(m/s);

```
       Depth  Amb-cur   P-dia  Polutnt   Dilutn  x-posn   y-posn    Time   Iso dia
Step     (m)  (cm/s)    (in) (col/dl)     ()      (m)      (m)      (s)      (m)
  0    18.15   1.400   2.343 2.590E+6   1.000     0.0      0.0      0.0  0.05945;  9.458 T-90hr,
 100   18.07   1.400   12.32 471750.7   5.490   0.639   -0.113   1.673   0.3130;  9.424 T-90hr,
 200   17.61   1.400   21.87 219905.3   11.77   1.318   -0.232   6.056   0.5554;  9.240 T-90hr,
 267   16.05   1.400   42.65  85238.4   30.34   2.296   -0.405   19.44   1.0826; trap level, merging; 8.615 T-90hr,
 300   15.34   1.400   63.27  67833.1   38.10   2.732   -0.482   28.58   1.6057;  8.339 T-90hr,
 318   15.20   1.400   71.39  65187.4   39.64   2.853   -0.503   31.31   1.8117; begin overlap;  8.285 T-90hr,
 400   14.95   1.400   94.95  62151.2   41.55   3.192   -0.563   39.26   2.4091;  8.187 T-90hr,
 480   14.90   1.400   102.6  61721.1   41.83   3.409   -0.601   44.43   2.6036; local maximum rise or fall;  8.170 T-90hr,
```

Horiz plane projections in effluent direction: radius(m): 0.0000; CL(m): 3.4620
Lmz(m): 3.4620
forced entrain 1 14.06 3.247 2.606 1.000
Rate sec-1 0.00019534 dy-1 16.8772 kt: 0.000078146 Amb Sal 29.1654
4/3 Power Law. Farfield dispersion based on wastefield width of 10.07 m

```
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)            (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 61721.1   41.83   10.08   3.462 2.78E-4     0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
 22115.3   634.0   211.0   183.0   3.563     0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
 3965.60   649.9   216.3   186.5   3.631     0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
count: 1
 ;
5:51:47 AM. amb fills: 4
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	41.83	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	10.07	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	3.462	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	183	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.48E-04	
4. Horizontal current speed (m/sec)	0.014	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	6.17E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo =	6.5237E-03 m^2/s
Beta =	5.5529E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	3.56E+00	179.538	183.00	3.30E+02	7.82E+03	331

Wrangell (model output for 1*depth, 2*depth, 5*depth and 10*depth)

Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Wrangell" memoQ=

Model configuration items checked: Brooks far-field solution; Report effective dilution;
Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
Bacteria model : Mancini (1978) coliform model
PDS sfc. model heat transfer : Medium
Equation of State : S, T
Similarity Profile : Default profile (k=2.0, ...)
Diffuser port contraction coefficient 0.61
Light absorption coefficient 0.16
Farfield increment (m) 200
UM3 aspiration coefficient 0.1
Output file: text output tab
Output each ?? steps 100
Maximum dilution reported 100000
Text output format : Standard
Max vertical reversals : to max rise or fall

/ UM3. 8/3/2021 9:23:16 AM
Case 1; ambient file C:\Plumes20\Wrangell_4_Aug16.004.db; Diffuser table record 2: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.040	90.00	11.00	11.30	0.0	0.000194	0.040	90.00	0.0003	8.178952
3.000	0.040	90.00	11.00	11.30	0.0	0.000194	0.040	90.00	0.0003	8.178952
6.000	0.040	90.00	11.20	12.70	0.0	0.000194	0.040	90.00	0.0003	8.137535
9.000	0.040	90.00	12.10	12.80	0.0	0.000194	0.040	90.00	0.0003	8.815796
12.00	0.040	90.00	12.80	11.90	0.0	0.000194	0.040	90.00	0.0003	9.487716
15.00	0.040	90.00	14.00	11.10	0.0	0.000194	0.040	90.00	0.0003	10.52628
18.00	0.040	90.00	14.90	11.10	0.0	0.000194	0.040	90.00	0.0003	11.22223
21.00	0.040	90.00	15.80	11.20	0.0	0.000194	0.040	90.00	0.0003	11.90396
24.00	0.040	90.00	16.20	11.00	0.0	0.000194	0.040	90.00	0.0003	12.24129
27.00	0.040	90.00	16.80	11.00	0.0	0.000194	0.040	90.00	0.0003	12.70520
30.00	0.040	90.00	16.90	10.90	0.0	0.000194	0.040	90.00	0.0003	12.79661
31.00	0.040	90.00	16.93	10.87	0.0	0.000194	0.040	90.00	0.0003	12.82707

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)

3.9500 0.0 90.000 0.0 0.0 8.0000 32.000 30.500 200.00 30.350 3.0000 0.0 18.400
1.91E+5

Simulation:
Froude No: 32.56; Strat No: 8.40E-4; Spcg No: 124.5; k: 85.17; eff den (sigmaT) -1.415928; eff vel 3.407(m/s);

```
      Depth  Amb-cur   P-dia  Polutnt  net Dil  x-posn  y-posn    Time   Iso dia
Step    (m)  (cm/s)     (in) (col/dl)       ()     (m)     (m)     (s)     (m)
   0  30.35   4.000   3.085 191000.0   1.000     0.0     0.0     0.0     0.0;  14.06 T-90hr,
 100  30.32   4.000   21.88  25869.1   7.383   0.000   1.223   1.461  0.5546;  14.05 T-90hr,
 200  29.23   4.000   75.55   6306.8   30.29   0.000   5.127   18.85  1.9038;  13.64 T-90hr,
 265  25.85   4.000   147.1   2462.3   77.57   0.000   9.228   57.16  3.6599; trap level;  12.34 T-90hr,
 300  24.85   4.000   191.4   1914.4   99.77   0.000   10.45   72.89  4.7344;  11.95 T-90hr,
 301  24.84   4.000   192.3   1907.0   100.2   0.000   10.47   73.16  4.7551; begin overlap;  11.95 T-90hr,
 400  24.32   4.000   227.5   1702.3   112.2   0.000   11.88   93.03  5.6075;  11.75 T-90hr,
 415  24.32   4.000   228.3   1697.3   112.5   0.000   12.05   95.47  5.6269; local maximum rise or fall;  11.75 T-90hr,
```

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 12.046
Lmz(m): 12.046
forced entrain 1 143.3 6.034 5.800 1.000
Rate sec-1 0.00019572 dy-1 16.9100 kt: 0.000054521 Amb Sal 16.2632
Plumes not merged, Brooks method may be overly conservative.
4/3 Power Law. Farfield dispersion based on wastefield width of 74.08 m

```
   conc  dilutn  width distnce   time bckgrnd   decay current cur-dir eddydif
(col/dl)           (m)     (m)   (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 1697.28   112.0   74.09   12.05 2.78E-4     0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
 1632.35   112.0   81.17   30.50   0.128     0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
 1668.65   112.4   85.91   42.55   0.212     0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
```

count: 1
;
9:23:18 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)		
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	112	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	74.08	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.05	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	30.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.04	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	1.70E+03	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT						
			Eo =	9.3337E-02	m^2/s	
			Beta =	3.7799E-01	unitless	
	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	0.128125	18.45	30.5	1.12E+02	1697	113

/ UM3. 8/3/2021 9:24:14 AM
Case 1; ambient file C:\Plumes20\Wrangell_4_Aug16.004.db; Diffuser table record 2: ---------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.040	90.00	11.00	11.30	0.0	0.000195	0.040	90.00	0.0003	8.178952
3.000	0.040	90.00	11.00	11.30	0.0	0.000196	0.040	90.00	0.0003	8.178952
6.000	0.040	90.00	11.20	12.70	0.0	0.000196	0.040	90.00	0.0003	8.137535
9.000	0.040	90.00	12.10	12.80	0.0	0.000196	0.040	90.00	0.0003	8.815796
12.00	0.040	90.00	12.80	11.90	0.0	0.000196	0.040	90.00	0.0003	9.487716
15.00	0.040	90.00	14.00	11.10	0.0	0.000196	0.040	90.00	0.0003	10.52628
18.00	0.040	90.00	14.90	11.10	0.0	0.000196	0.040	90.00	0.0003	11.22223
21.00	0.040	90.00	15.80	11.20	0.0	0.000196	0.040	90.00	0.0003	11.90396
24.00	0.040	90.00	16.20	11.00	0.0	0.000196	0.040	90.00	0.0003	12.24129
27.00	0.040	90.00	16.80	11.00	0.0	0.000196	0.040	90.00	0.0003	12.70520
30.00	0.040	90.00	16.90	10.90	0.0	0.000196	0.040	90.00	0.0003	12.79661
31.00	0.040	90.00	16.93	10.87	0.0	0.000196	0.040	90.00	0.0003	12.82707

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.9500	0.0	90.000	0.0	0.0	8.0000	32.000	61.000	200.00	30.350	3.0000	0.0	18.400	1.91E+5

Simulation:
Froude No: 32.56; Strat No: 8.40E-4; Spcg No: 124.5; k: 85.17; eff den (sigmaT) -1.415928; eff vel 3.407(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	net Dil	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)	
0	30.35	4.000	3.085	191000.0	1.000	0.0	0.0	0.0	0.07603;	14.06 T-90hr,
100	30.32	4.000	21.88	25869.1	7.383	0.000	1.223	1.461	0.5546;	14.05 T-90hr,
200	29.23	4.000	75.55	6306.8	30.29	0.000	5.127	18.85	1.9038;	13.64 T-90hr,
265	25.85	4.000	147.1	2462.3	77.57	0.000	9.228	57.16	3.6599;	trap level; 12.34 T-90hr,
300	24.85	4.000	191.4	1914.4	99.77	0.000	10.45	72.89	4.7344;	11.95 T-90hr,
301	24.84	4.000	192.3	1907.0	100.2	0.000	10.47	73.16	4.7551;	begin overlap; 11.95 T-90hr,
400	24.32	4.000	227.5	1702.3	112.2	0.000	11.88	93.03	5.6075;	11.75 T-90hr,
415	24.32	4.000	228.3	1697.3	112.5	0.000	12.05	95.47	5.6269;	local maximum rise or fall; 11.75 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 12.046
Lmz(m): 12.046
forced entrain 1 143.3 6.034 5.800 1.000
Rate sec-1 0.00019572 dy-1 16.9100 kt: 0.000054521 Amb Sal 16.2632
Plumes not merged, Brooks method may be overly conservative.
4/3 Power Law. Farfield dispersion based on wastefield width of 74.08 m

```
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)            (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 1697.28   112.0   74.09   12.05 2.78E-4    0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
 1565.88   114.7   93.35   61.00   0.340    0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
 1596.09   117.5   98.31   73.05   0.424    0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
count: 1
 ;
9:24:14 AM. amb fills: 4
```

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)		
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	112	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	74.08	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.05	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	61	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.04	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	1.70E+03	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 9.3337E-02 m^2/s
Beta = 3.7799E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	0.339930556	48.95	61	1.15E+02	1657	115

/ UM3. 8/3/2021 9:24:33 AM
Case 1; ambient file C:\Plumes20\Wrangell_4_Aug16.004.db; Diffuser table record 2: ---------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.040	90.00	11.00	11.30	0.0	0.000195	0.040	90.00	0.0003	8.178952
3.000	0.040	90.00	11.00	11.30	0.0	0.000196	0.040	90.00	0.0003	8.178952
6.000	0.040	90.00	11.20	12.70	0.0	0.000196	0.040	90.00	0.0003	8.137535
9.000	0.040	90.00	12.10	12.80	0.0	0.000196	0.040	90.00	0.0003	8.815796
12.00	0.040	90.00	12.80	11.90	0.0	0.000196	0.040	90.00	0.0003	9.487716
15.00	0.040	90.00	14.00	11.10	0.0	0.000196	0.040	90.00	0.0003	10.52628
18.00	0.040	90.00	14.90	11.10	0.0	0.000196	0.040	90.00	0.0003	11.22223
21.00	0.040	90.00	15.80	11.20	0.0	0.000196	0.040	90.00	0.0003	11.90396
24.00	0.040	90.00	16.20	11.00	0.0	0.000196	0.040	90.00	0.0003	12.24129
27.00	0.040	90.00	16.80	11.00	0.0	0.000196	0.040	90.00	0.0003	12.70520
30.00	0.040	90.00	16.90	10.90	0.0	0.000196	0.040	90.00	0.0003	12.79661
31.00	0.040	90.00	16.93	10.87	0.0	0.000196	0.040	90.00	0.0003	12.82707

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.9500	0.0	90.000	0.0	0.0	8.0000	32.000	152.50	200.00	30.350	3.0000	0.0	18.400	1.91E+5

Simulation:
Froude No: 32.56; Strat No: 8.40E-4; Spcg No: 124.5; k: 85.17; eff den (sigmaT) -1.415928; eff vel 3.407(m/s);

Step	Depth (m)	Amb-cur (cm/s)	P-dia (in)	Polutnt (col/dl)	net Dil ()	x-posn (m)	y-posn (m)	Time (s)	Iso dia (m)
0	30.35	4.000	3.085	191000.0	1.000	0.0	0.0	0.0	0.07603; 14.06 T-90hr,
100	30.32	4.000	21.88	25869.1	7.383	0.000	1.223	1.461	0.5546; 14.05 T-90hr,
200	29.23	4.000	75.55	6306.8	30.29	0.000	5.127	18.85	1.9038; 13.64 T-90hr,
265	25.85	4.000	147.1	2462.3	77.57	0.000	9.228	57.16	3.6599; trap level; 12.34 T-90hr,
300	24.85	4.000	191.4	1914.4	99.77	0.000	10.45	72.89	4.7344; 11.95 T-90hr,
301	24.84	4.000	192.3	1907.0	100.2	0.000	10.47	73.16	4.7551; begin overlap; 11.95 T-90hr,
400	24.32	4.000	227.5	1702.3	112.2	0.000	11.88	93.03	5.6075; 11.75 T-90hr,
415	24.32	4.000	228.3	1697.3	112.5	0.000	12.05	95.47	5.6269; local maximum rise or fall; 11.75 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 12.046
Lmz(m): 12.046
forced entrain 1 143.3 6.034 5.800 1.000
Rate sec-1 0.00019572 dy-1 16.9100 kt: 0.000054521 Amb Sal 16.2632
Plumes not merged, Brooks method may be overly conservative.
4/3 Power Law. Farfield dispersion based on wastefield width of 74.08 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif

(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
1697.28 112.0 74.09 12.05 2.78E-4 0.0 16.34 4.000 90.00 3.00E-4 5.4521E-5
1382.28 148.5 133.1 152.5 0.976 0.0 16.34 4.000 90.00 3.00E-4 5.4521E-5
1220.33 154.2 138.7 164.5 1.059 0.0 16.34 4.000 90.00 3.00E-4 5.4521E-5
count: 1
;
9:24:33 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
		4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	112	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	74.08	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.05	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	152.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.04	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	1.70E+03	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 9.3337E-02 m^2/s
Beta = 3.7799E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	0.975347222	140.45	152.5	1.49E+02	1280	149

/ UM3. 8/3/2021 9:24:50 AM
Case 1; ambient file C:\Plumes20\Wrangell_4_Aug16.004.db; Diffuser table record 2: ---------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.040	90.00	11.00	11.30	0.0	0.000195	0.040	90.00	0.0003	8.178952
3.000	0.040	90.00	11.00	11.30	0.0	0.000196	0.040	90.00	0.0003	8.178952
6.000	0.040	90.00	11.20	12.70	0.0	0.000196	0.040	90.00	0.0003	8.137535
9.000	0.040	90.00	12.10	12.80	0.0	0.000196	0.040	90.00	0.0003	8.815796
12.00	0.040	90.00	12.80	11.90	0.0	0.000196	0.040	90.00	0.0003	9.487716
15.00	0.040	90.00	14.00	11.10	0.0	0.000196	0.040	90.00	0.0003	10.52628
18.00	0.040	90.00	14.90	11.10	0.0	0.000196	0.040	90.00	0.0003	11.22223
21.00	0.040	90.00	15.80	11.20	0.0	0.000196	0.040	90.00	0.0003	11.90396
24.00	0.040	90.00	16.20	11.00	0.0	0.000196	0.040	90.00	0.0003	12.24129
27.00	0.040	90.00	16.80	11.00	0.0	0.000196	0.040	90.00	0.0003	12.70520
30.00	0.040	90.00	16.90	10.90	0.0	0.000196	0.040	90.00	0.0003	12.79661
31.00	0.040	90.00	16.93	10.87	0.0	0.000196	0.040	90.00	0.0003	12.82707

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.9500	0.0	90.000	0.0	0.0	8.0000	32.000	305.00	200.00	30.350	3.0000	0.0	18.400	1.91E+5

Simulation:
Froude No: 32.56; Strat No: 8.40E-4; Spcg No: 124.5; k: 85.17; eff den (sigmaT) -1.415928; eff vel 3.407(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	net Dil	x-posn	y-posn	Time	Iso dia
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)
0	30.35	4.000	3.085	191000.0	1.000	0.0	0.0	0.0	0.07603; 14.06 T-90hr,
100	30.32	4.000	21.88	25869.1	7.383	0.000	1.223	1.461	0.5546; 14.05 T-90hr,
200	29.23	4.000	75.55	6306.8	30.29	0.000	5.127	18.85	1.9038; 13.64 T-90hr,
265	25.85	4.000	147.1	2462.3	77.57	0.000	9.228	57.16	3.6599; trap level; 12.34 T-90hr,
300	24.85	4.000	191.4	1914.4	99.77	0.000	10.45	72.89	4.7344; 11.95 T-90hr,
301	24.84	4.000	192.3	1907.0	100.2	0.000	10.47	73.16	4.7551; begin overlap; 11.95 T-90hr,
400	24.32	4.000	227.5	1702.3	112.2	0.000	11.88	93.03	5.6075; 11.75 T-90hr,
415	24.32	4.000	228.3	1697.3	112.5	0.000	12.05	95.47	5.6269; local maximum rise or fall; 11.75 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 12.046
Lmz(m): 12.046
forced entrain 1 143.3 6.034 5.800 1.000
Rate sec-1 0.00019572 dy-1 16.9100 kt: 0.000054521 Amb Sal 16.2632
Plumes not merged, Brooks method may be overly conservative.
4/3 Power Law. Farfield dispersion based on wastefield width of 74.08 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif

(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
1697.28 112.0 74.09 12.05 2.78E-4 0.0 16.34 4.000 90.00 3.00E-4 5.4521E-5
1295.62 171.8 155.5 200.0 1.306 0.0 16.34 4.000 90.00 3.00E-4 5.4521E-5
819.357 286.6 261.7 400.0 2.694 0.0 16.34 4.000 90.00 3.00E-4 5.4521E-5
642.616 294.2 268.7 412.0 2.778 0.0 16.34 4.000 90.00 3.00E-4 5.4521E-5
count: 2
;
9:24:50 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)		
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	112	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	74.08	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.05	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	305	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.04	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	1.70E+03	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 9.3337E-02 m^2/s
Beta = 3.7799E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	2.034375	292.95	305	2.29E+02	829	230